

RECHARGING OF APPALACHIAN AQUIFERS

**WITH
MOUNTAIN TOP
REMOVAL
APPLICATIONS**

BY

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RECHARGING APPALACHIAN AQUIFIERS USING WATERSHED SPECIFIC TECHNOLOGY AND METHODOLOGY AND TECHNICAL CONSIDERATIONS RELATIVE TO MOUNTAIN TOP REMOVAL

by L. C. Nelson, W. K. Sawyer, and L. Z. Shuck

Introduction

Rapid runoff of surface water in Appalachia has many catastrophic effects not only on people, but all aspects of watershed, stream and river ecosystems. Rapid runoff contributes to at least five major problems, which themselves create other problems. Namely, 1) flash floods, 2) serious erosion, 3) less than capacity aquifer recharging, 4) alter seasonal variation in flows and total volumes of water in Appalachian branches, creeks, streams, and rivers. Implications include filling up of dams, reservoirs, and river bottoms with eroded soils, loss of human lives and hom aquatic life habitat impairment or eradication, reduction or elimination of capacity to support various aquatic species changing the characteristics of streams in general, and eventual extinction of species. Last, but far from least significant, is the Appalachian region economic impact. The economic impact is not just limited to flood disaster damages, but includes the number two industry in WV of tourism and recreation, loss of use of valuable property in flood prone areas, and less residence time of rainfall-based water in Appalachia enroute to the Gulf of Mexico and the Atlantic Ocean.

Salvaging a higher percentage of rainfall to recharge Appalachian aquifers needs to be a direct objective and goal of industrial and environmental activities. The aquifers of concern here are not the ones that usually come to mind that include ground water and those directly associated with water wells. The aquifers of interest here are the ones that control the flow rates of springs out of the mountainside, seeps, and small flows in branches, creeks. These are the temporary storage aquifers above the elevations of the hollows with the branches or small streams up to large rivers. These are called temporary storage aquifers because they are "above-drainage" aquifers. They are the aquifers that provide the storage volumes and pressure to maintain and meter the flows during the three to four months of low rainfall in the summer and fall.

The recharging of these above-drainage aquifers should have major priority and consideration. Like half charged batteries, aquifers undercharged with less hydrostatic "head" pressure suffer lower current flow rates through the porous, permeable, and fractured reservoir rocks, as well as a reduced capacity to deliver low temperature (52 to 60 °F) purified water to streams during the several months of low seasonal rainfall. This results in a higher percentage or concentration of surface contaminated water in creeks, streams and rivers, and higher water temperatures. Unfortunately, nature's filtration-purification-cooling process for streams is being bypassed as a result of human activities of timbering, mineral and energy resource extraction, concrete and asphalt roads, cities, malls and parking and ditches, sanitary and storm sewer lines, roof gutter water concentrations, etc. The basic **distributed**, spongy system has been altered to a **concentrated**, channeled, accelerated-flow, aquifer-bypassing system. Such activities as timbering, especially clear cutting, greatly accelerate the rapid runoff of water down the mountainsides, creating gullies, huge erosion problems, and the huge problem no one seems to talk about, or even know about, **the bypassing of above-drainage aquifers** and temporary storage reservoirs. These above-drainage aquifers are fed by rainfall entering the more open vertical natural fracture systems that serve as conduits down to different layers of porous, permeable sandstones that store the water until it can be further metered out through the combined fractured and porous lower rock formations and into the branches and streams in the hollows. These phenomena of fracture systems and water seeps or flows may be observed along all Appalachian highway cuts through the hilltops.

First, we have to understand the realities of the system of layered media, some porous and permeable, and some with negligible permeability or porosity, but with a network of vertical natural fracture systems. Second, it is required to develop the technology and methodology with intestinal fortitude to restore the more natural, gradual processes, or improve upon them. This paper attempts to realistically characterize aquifer systems and the recharging process. It coincidentally implicates the highly emotional and controversial issue of mountain top removal as runoff mitigation methodology is examined. **In fact, this paper introduces a concept for solving two major Appalachian region problems with one single plan.** The roles natural fracture systems, joints, faults and other types of discontinuities in strata play in in-situ mineral extraction or hydrologic processes are often ignored in analysis methodology, and seldom used in design. Calculations are made and illustrated here using simple, easily visualized models to illustrate the importance of such technical considerations, and the availability of a huge body of technology developed over 30 years at costs exceeding 100 million dollars that is available to focus on the problem.

Aquifer Characteristics

It is instructive to briefly consider the origin and history of aquifers that leads to their present day characteristics. Although widely varying, many of the aquifer rocks of interest here in Appalachia that are above drainage were formed by sediments in deep lakes and riverbeds during the Quaternary or Paleozoic Ages and Permian and Pennsylvanian Periods, many millions of years ago. Every several thousands of years some catastrophic event would abruptly, in geologic times, alter the types of aquatic life and mineral matter settling to the bottom, thus creating alternating layers of sand, clay, lime, and carbonaceous matter that became solidified under high pressure over millions of years. That is why we have relatively uniform layers of sandstone, limestone, shale, coal, red rock, slate, and clay, varying from several inches to hundreds of feet thick, making up the complex stratigraphic column found throughout the Appalachian Basin. Then, along came the Appalachian orogeny when the continents collided and created the Appalachian mountain range. This cataclysmic event, along with more recent tectonic events, over thousands of years gave us the beautiful mountains of folded, faulted, fractured, up and down thrust rock layers, and sloping, undulating coal beds. A magnificent cross section of about 1,100' of exposed rocks can be observed along U.S. Rt. 19 S up Pow mountain (which is a potentially great geological observatory that remains a WV undeveloped resource). Just about every conceivable geological feature can be observed in this section. At the top of Rt 52 in a narrow highway cut about 500' above Bluefield State College in Bluefield, WV, rock layers thrust up over 75 degrees can readily be observed. It should easily be visualized and understood that the rock layers making up aquifers are not just large masses of isotropic, homogeneous substances. Thousands of feet of the Appalachian mountains have now been eroded away over thousands of years, stress relieving the rocks created under high pressures and temperatures. For thousands of years until a few hundred years ago, these mountains were capped with trees and dense vegetation, and now mankind has dramatically changed it. One might speculate philosophically, that man has removed the sponge and time-delay mechanism nature built in to protect its amenities of streams full of life, and protect itself from self-destruction.

One interesting feature man has not changed, but usually ignores, is the major and minor sets of natural fracture systems that extend across different layers and often continuously, with minor offsets, for hundreds and thousands of feet both vertically and horizontally. All rocks in Appalachia have these fracture networks to a greater or lesser degree as do most parts of the earth. Some of these fractures, of varying width from inches to feet, are partially open. Most are partly filled and propped open with porous infiltrated matter from above or below, and remain highly permeable, although some are sealed by a squeezing of the lower shear modulus, viscoplastic clay layers. These fracture networks constitute the major conduit system for recharging aquifers since impermeable clay layers periodically separate the porous layers of rocks. Water flows down the fractures rapidly, and then more slowly out into the different layers of porous rocks recharging the bottom layers first, and as they fill up, the next higher layers progressively absorb the water.

The aquifer storage capacities are actually the large volumes of porous, permeable sandstone, limestone or shale layers with large pore volumes of 5 to 30 percent, and permeabilities (connectivity of pore volumes) ranging from a few milidarcies to a few darcies through which the water seeps. The permeability of the rock may also vary with direction by a factor of 2 or more. The fracture systems vary in orientation, but quite often the major system has a general N4 trending orientation, and the minor, less continuous system is usually more or less than 90 degrees forming an approximate orthogonal network. The permeability of these above-drainage fracture systems is often an order of magnitude greater than the adjacent strata, which makes them a **primary** consideration in recharging aquifers. This is true in the above drainage cases where the eroded valleys have created isolated mountaintops and have removed the horizontal in situ stress fields, allowing greater expansion of the vertical fractures. These are the fracture systems in layered porous aquifers that are of interest for stream recharging, as opposed to the deeper, below drainage aquifers typically used for well water and most ground water studies. The orientation and characteristics of these fracture systems and the orientation of principal in situ stresses greatly influence mining, oil and gas extraction, and groundwater flow, yet receive no consideration, and not even mentioned in mountain top removal, for example. For sake of illustration, a couple of sets of conditions will be used along with a sophisticated, tested and proven, computer reservoir simulation program to calculate and show the huge differences resulting from different mountain (original back-filled) slopes. Other calculations can readily be made to illustrate the significance of natural fracture system orientations.

Consider two geometrical conditions consisting of 1) a flattened mountaintop with a small 4-degree inward slope to form a slight concave surface, and 2) a conventional, 25 degree slope. Then consider a stratigraphic column of layers media including topsoil, and a series of varying thickness, porosity and permeability layers with a vertical fracture network or grid. **The same stratigraphic column with the same porosity, permeability, and thickness layers is used for both the concave (4-degree) and 25 degree slope cases. For the sake of illustration, the usual irregular spacing between fractures that typically ranges from 2' to 50' is taken as an average of 25' for both cases. The permeability of the major fractures is often 3 times or more greater than the permeability of the minor set. The permeability of the major fracture system is assumed to be a factor of 20 greater than the top strata. The percents of incident rain absorbed or captured that do not run off are calculated and compared with the results of two forest covered mountains, one of zero and the other a 25 degree slope. A rainfall rate of 0.5"/hr for a period of 24 hours is assumed. The properties of each layer of rock are the same for each calculation. A panel arbitrarily chosen here as 500' wide by 1,000' long.**

Computer simulation of the flow conditions was used to calculate the percent of rainfall captured versus runoff for comparison purposes to illustrate the importance of such considerations. This is not intended to be a comprehensive simulation of any specific, complex, actual strata, but rather an illustration to emphasize that consideration should be given to technical aspects of aquifer recharging, especially in conjunction with a created resource opportunity involving mountaintop removal.

Summary, Conclusions, and Considerations Based upon Science and Technology, and Simulation Model Calculations

I. Enhancing aquifer recharging in Appalachia is essential for sustainability of economy and watershed ecosystems with the continued industrial and other accelerated land use development in Appalachia. Continued development, as in the past, will result in unacceptable degradation of our watershed, stream and river ecosystems at some time in the near future, and a correspondingly substantial economic impact will also be realized. The simulation shows that 45% or more of the rainfall would be lost (i.e. not available for aquifer recharge) due to runoff and/or retention by mountain foliage. Normally, channeling occurs and deep gullies down hillsides form quickly in sloped loose clay or topsoil shortly during onset of rain. Mountain surfaces are mostly curved as opposed to planar, such that real runoff flows are not

Summary, Conclusions, and Considerations Based upon Science and Technology, and Simulation Model Calculations (Cont'd)

I. (Cont'd)

uniformly distributed, which gives a much worse runoff condition than the ones calculated and illustrated here. The actual, typical runoff and non-capture rates are probably at least 50% higher than those calculated here, which means that we typically may capture less than 20% of the incident rainfall in the above drainage aquifers. This is a very serious problem for small streams in Appalachia.

II. Mountaintop removal can create a real asset for capturing rainwater and preventing runoff. Today, the flattened mountaintops are being rounded and sloped so that water will run off and quickly leave the Appalachian Basin. **This is just the opposite of what science and technology tells us we should be doing.** Back-filling, although aesthetically pleasing, is also the worst possible thing to do in so far as recharging of aquifers from rain water.

III. Creating a very shallow circular or elliptical crater with an inward slope less than 6 degrees, that would store water only 5 to 10 feet deep temporarily at the center and deepest point based upon largest estimated rainfall rates, and aligned properly with fracture patterns would capture 100 percent of the incident rain and snow fall. Such temporary storage ponds on valley-fills and immediately under the removed coal could **simultaneously serve FIVE VALUABLE PURPOSES**: 1) capture 100 percent of incident rainwater and snow, 2) recharge local above drainage aquifers, 3) provide the best flood and erosion control measure available, that is, **stopped at the source**, 4) serve as a great wetland for treating acid rain, and for wildlife, and 5) serve as an accelerated method of reforestation, because the trees would have a much larger quantity of available water. Water loving tree forests or other water loving vegetation crops for periodic harvest could be planted. These are serious benefits that need to be publicly recognized and quickly implemented into reclamation plans all across Appalachia.

This time-delay, capture process gives aquifers time to soak up the water at their own rates based upon their own peculiar characteristics **better than the original forested mountaintops.**

IV. The earth's real features of natural fracture systems and in-situ stresses that produce highly directional flow characteristics in the recharging of aquifers need to be given special consideration, with reclamation designs and protocols based upon them, not an arbitrary shape or slope angle backfill regulation/rule.

V. Special geometric configurations conducive to temporary storage of rainwater for periods of hours, several days, weeks, or months, could be integrally designed into valley fills and mountain top leveling so that fills breakout and other undesirable features can be circumvented.

VI. The result of valley fill and mountaintop leveling can be a huge asset condition, for slight further modification and improvement for recharging Appalachian aquifers. Back-filling or sloping outward destroys this opportunity, and also creates the worst condition for aquifer recharging. **We must base our reclamation designs upon science and technology, not emotion and news media hype.**

Summary, Conclusions, and Considerations Based upon Science and Technology, and Simulation Model Calculations (Cont'd)

- VII. Reclamation pools can improve entire watershed and stream ecosystem habitats by sustaining higher flow rates of purified water from aquifers into streams during a critical period of the annual 1/4 year cycle of decreased rainfall. Likewise, retention times, and larger volumes of rainfall can be conserved and effectively used in Appalachia to improve watershed ecosystems before leaving for the Gulf of Mexico. Small branches, creeks and streams are critical sources of the food chain for aquatic species, spawning, other vital processes, and thermal pollution for larger streams and rivers. These are the streams in which aquatic life are stressed the most, and generally impacted the most, during the dry season. That is why this process is so important to the overall health of all Appalachian stream and river ecosystems.
- VIII. Erosion damage can be virtually eliminated from mining and valley fill operations, even below the original forested level, in future industrial development areas by mountaintop removal and valley fill enhanced designs.
- IX. Reclamation pools on top of valley fills are actually a better long-term flood control process than dams across rivers, because 1) the dams across rivers and their storage capacity will fill up in 50 years or so, and 2) Erosion is stopped at the source so that it does not occur in the first place.
- X. Recharging aquifers using time-delay, fracture absorption designs above drainage should be a major consideration in all aspects of industrial development, environmental problem mitigation, recreational and other land use in Appalachia in the future.
- XI. Recharging the above-drainage aquifers will also help recharge below drainage aquifers and the groundwater that flows into water wells. Destroying the above-drainage aquifers can be a major reason the below-drainage aquifers are readily pressure depleted and domestic water wells go dry.
- XII. Mountaintop removal has many negative implications which have been highly publicized and polarizing. Yet, aside from a method for safe and economical coal recovery and reclaimed land use possibilities, the opportunity to enhance recharging of our aquifers is very attractive. Here is an opportunity to take a very negative situation and turn it around into a positive situation, by using it as a resource to create something very beneficial to our streams and their ecosystems.
- XIII. As part of the State's and Federal Government's plans, the mountaintops were supposed to be utilized for recreational or economic development. Recharging Appalachian Aquifers and the several other benefits stemming from this process should certainly qualify in all respects for this part of the plan.
- XIV. It is therefore recommended that a Feasibility Demonstration Project be developed in Southern West Virginia at the earliest possible date.

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A blue sunburst graphic with multiple rays emanating from a central point below the title, extending downwards towards the subtitle.

**WITH
MOUNTAIN TOP
REMOVAL
APPLICATIONS**

RECHARGING OF APPALACHIAN AQUIFERS



- **ACTION PLANS NEEDED FOR ABOVE DRAINAGE AQUIFERS**
- **NEED SCHEMES & PROCESSES OF LARGE IMPACT APPLIED AT STRATEGIC SITES**
- **MINOR ADJUSTMENTS NOT SUFFICIENT TO COUNTER 50 YRS OF INDUSTRIAL, COMMERCIAL & RESIDENTIAL IMPACTS**
- **MINOR ADJUSTMENTS INSUFFICIENT TO COUNTER LAND DEVELOPMENT RATES**
 - **HIGHWAYS, PARKING LOTS**
 - **ROOF DRAINS TO STORM DRAINS TO RIVERS**
 - **TIMBERING, FOREST TO GRASSLAND, YARDS**

RESULTS:

- 1. RAINWATER RETENTION TIME DWINDLING**
- 2. MANY STREAMS ECOSYSTEMS SEVERELY STRESSED**
- 3. MUST CAPTURE MORE OF THE RAINFALL IN AQUIFERS**

WHAT IS HAPPENING?

**RAPID RUNOFF IS BYPASSING
THE ABOVE DRAINAGE
AQUIFERS THAT PROVIDE THE
SEEPS AND SPRINGS THAT
ORIGINALLY PROVIDED
SUSTAINED FLOWS DURING 3
TO 4 MONTHS OF YEAR**

PROBLEMS?

- **LESS WATER, LOWER FLOW RATES IN STREAMS**
- **HIGHER TEMPERATURES OF CREEK WATER**
- **HIGHER % OF CREEK WATER IS SURFACE WATER**
- **GROUND WATER PURIFIED AND 55 TO 65 °F**
- **SURFACE WATER POLLUTED AND 75 TO 85 °F**
- **STREAM BEDS DRY & POLLUTANTS CONCENTRATED**

OPTIONS?

SMALL **IMPACT** BY CITY PLANNING---NO SPACE

SMALL **IMPACT** BY BUFFER ZONES, REVEGETATION

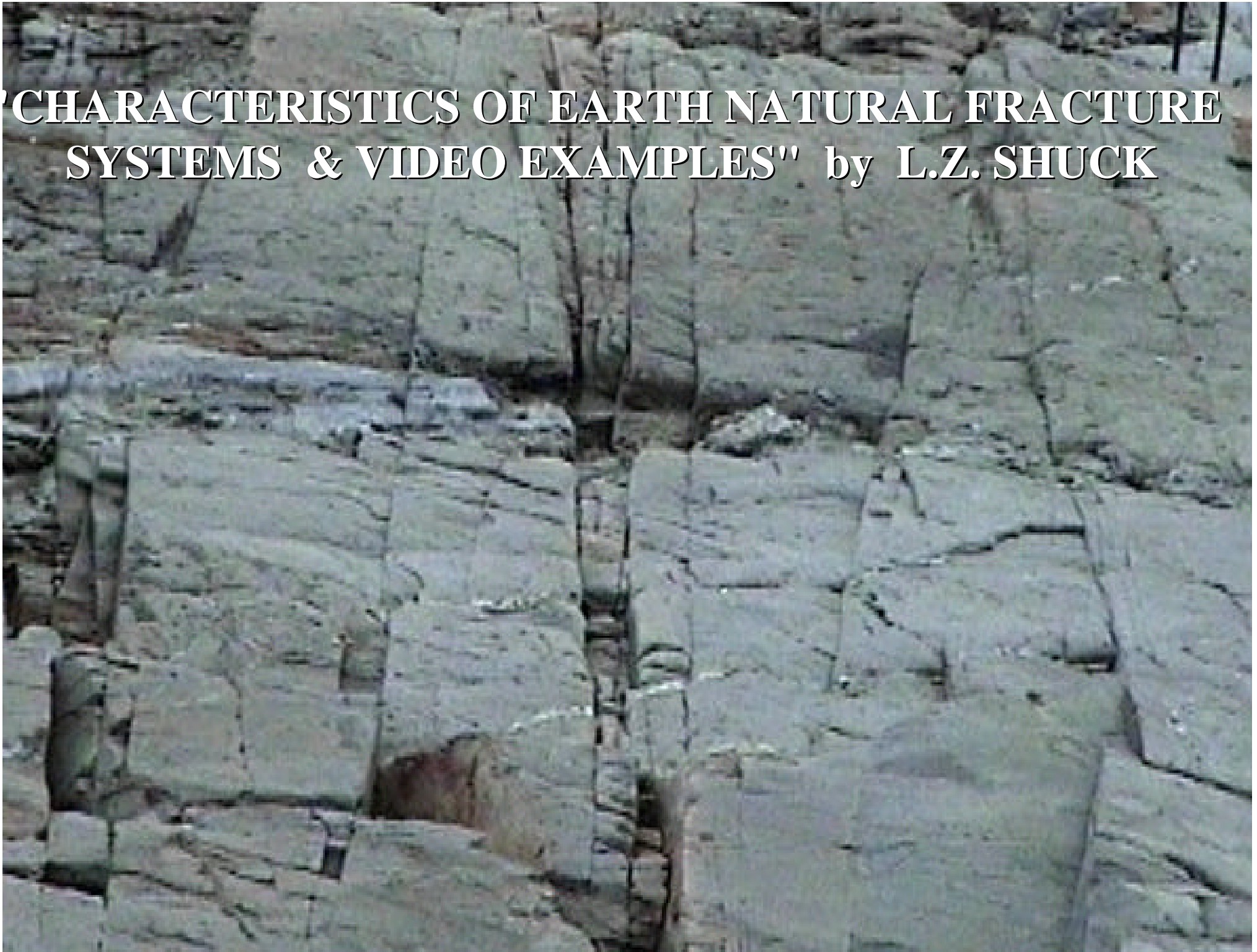
- LARGE **IMPACT** IDEAS NEEDED
- ABOVE DRAINAGE AQUIFERS NEED TO BE RECHARGED BY CAPTURE OF MORE RAIN WATER --- ON MOUNTAIN TOPS

HOW?

A CONCEPT FOR YOU TO CONSIDER

- **PLATEAUS OR FLATTENED MOUNTAIN TOPS FROM MINING THAT ARE STILL 150' OR MORE ABOVE DRAINAGE COULD BE CONVERTED TO STORAGE RESERVOIRS AND WETLANDS BY MAKING TOPS CONCAVE TO TRAP AND POOL RAINWATER A FEW FEET DEEP.**
- **100 % INCIDENT RAIN CAPTURED**
- **HUGE BODY OF TECHNOLOGY AVAILABLE FOR IMMEDIATE APPLICATION**

"CHARACTERISTICS OF EARTH NATURAL FRACTURE SYSTEMS & VIDEO EXAMPLES" by L.Z. SHUCK





















**"FRACTURED RESERVOIR MODELING AND
SIMULATION TECHNOLOGY DEVELOPED OVER 30
YEARS & \$ MILLIONS, & A MOUNTAINTOP
RESERVOIR SIMULATION EXAMPLE"**

by W.K.SAWYER

**"SUMMARY, CONCLUSIONS, AND
RECOMMENDATION",**

by L. C. NELSON

Improved Aquifer Recharge With Mountain Top Removal

**by
Walter K. Sawyer**

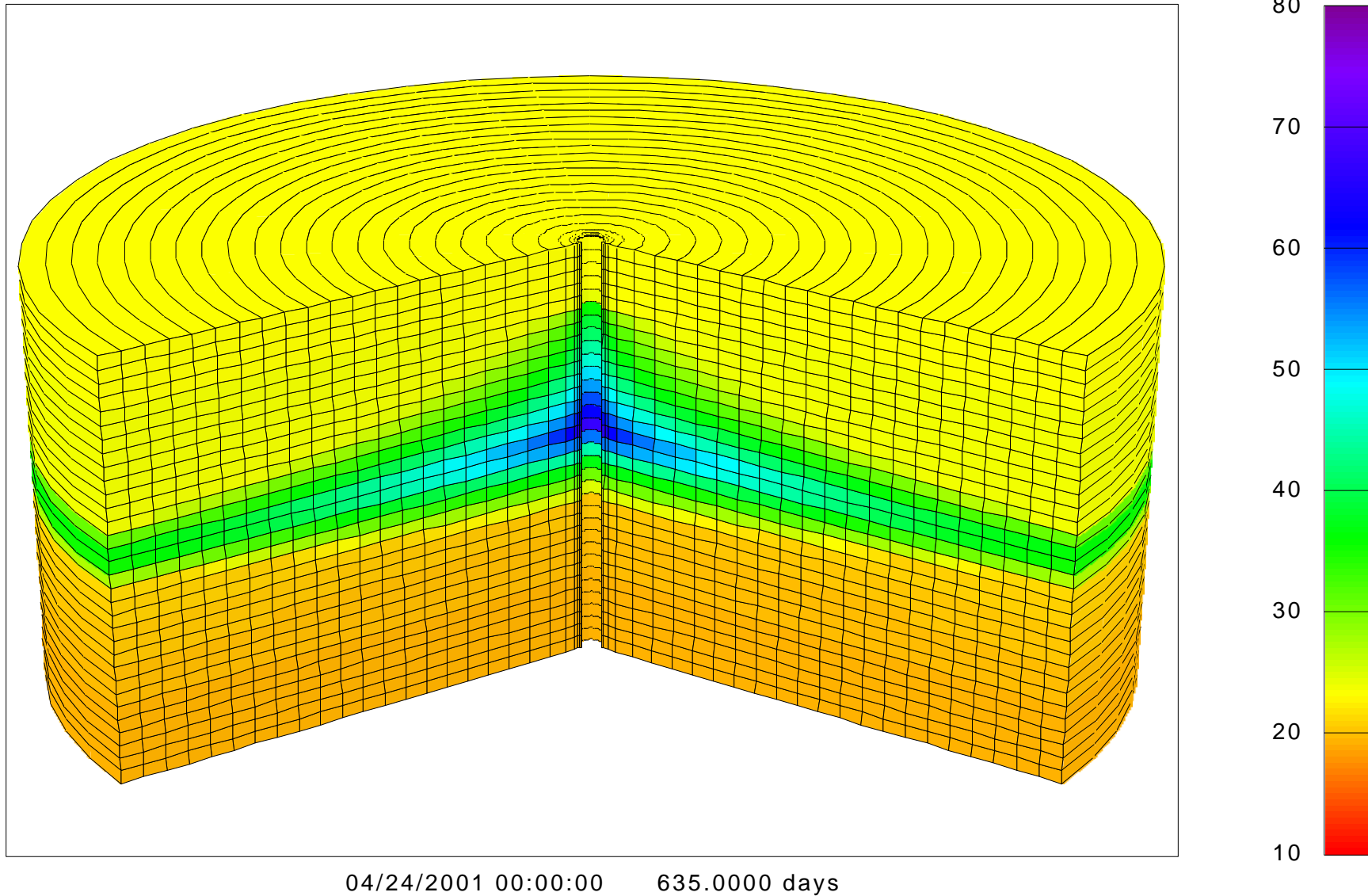
Holditch - Reservoir Technologies Consulting Services

Pittsburgh, Pennsylvania

Water Injection into Vertical Wellbore - Radial Geometry

Pressure distribution after 635 days

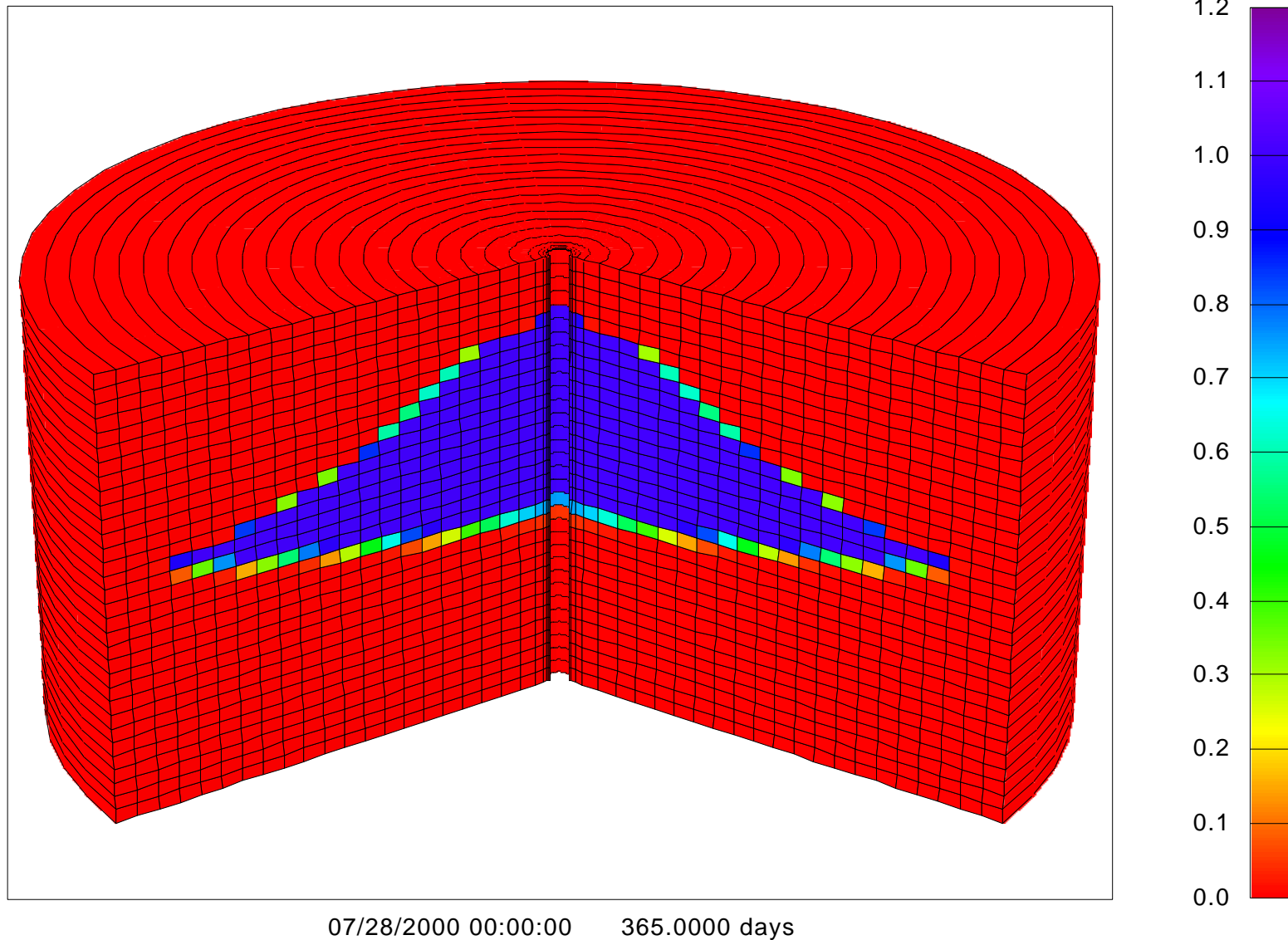
A0003 - Water Pressure (psia)



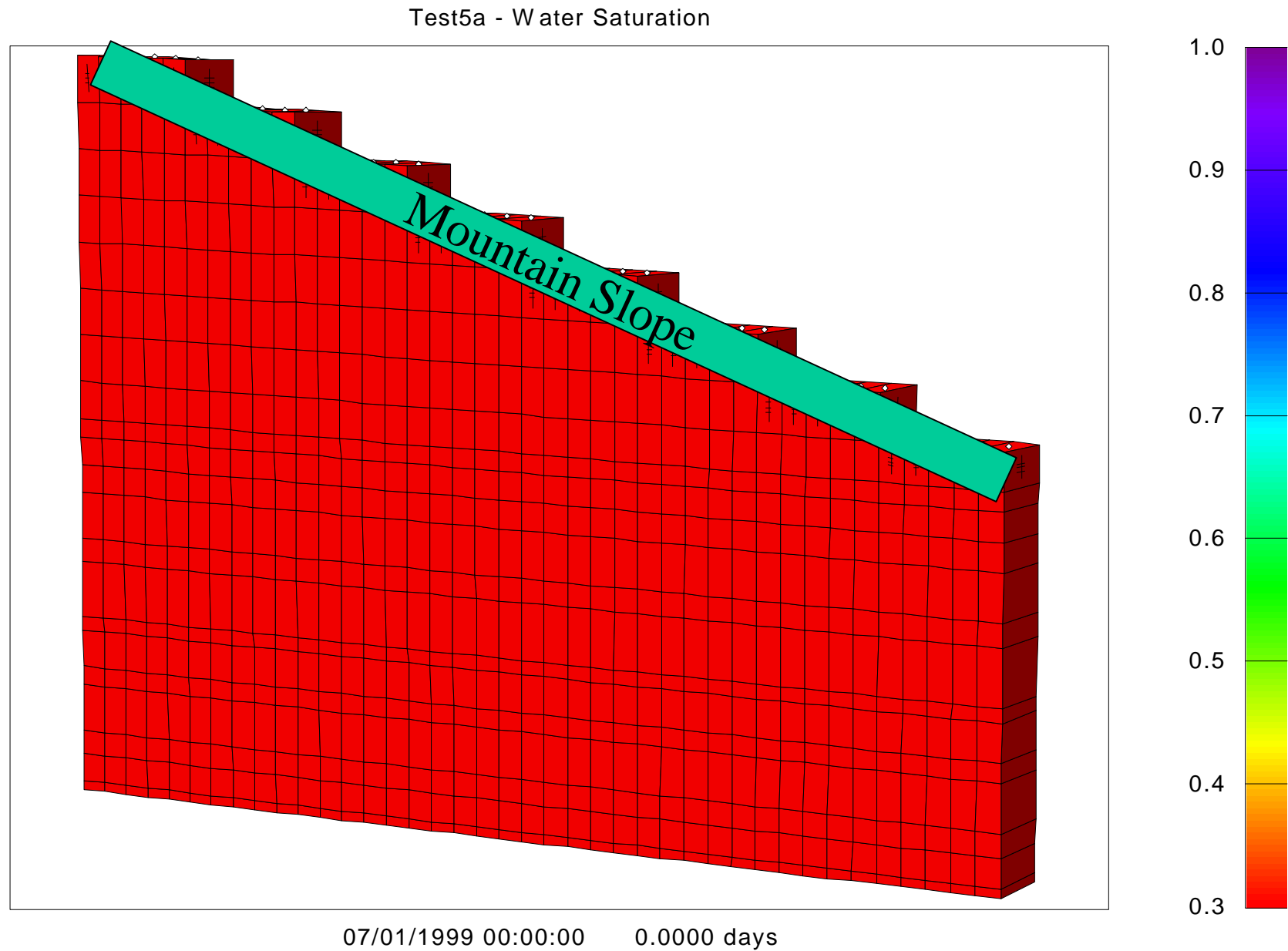
Water Injection into Vertical Wellbore - Radial Geometry

Water saturation distribution after 365 days

A0003 - Water Saturation

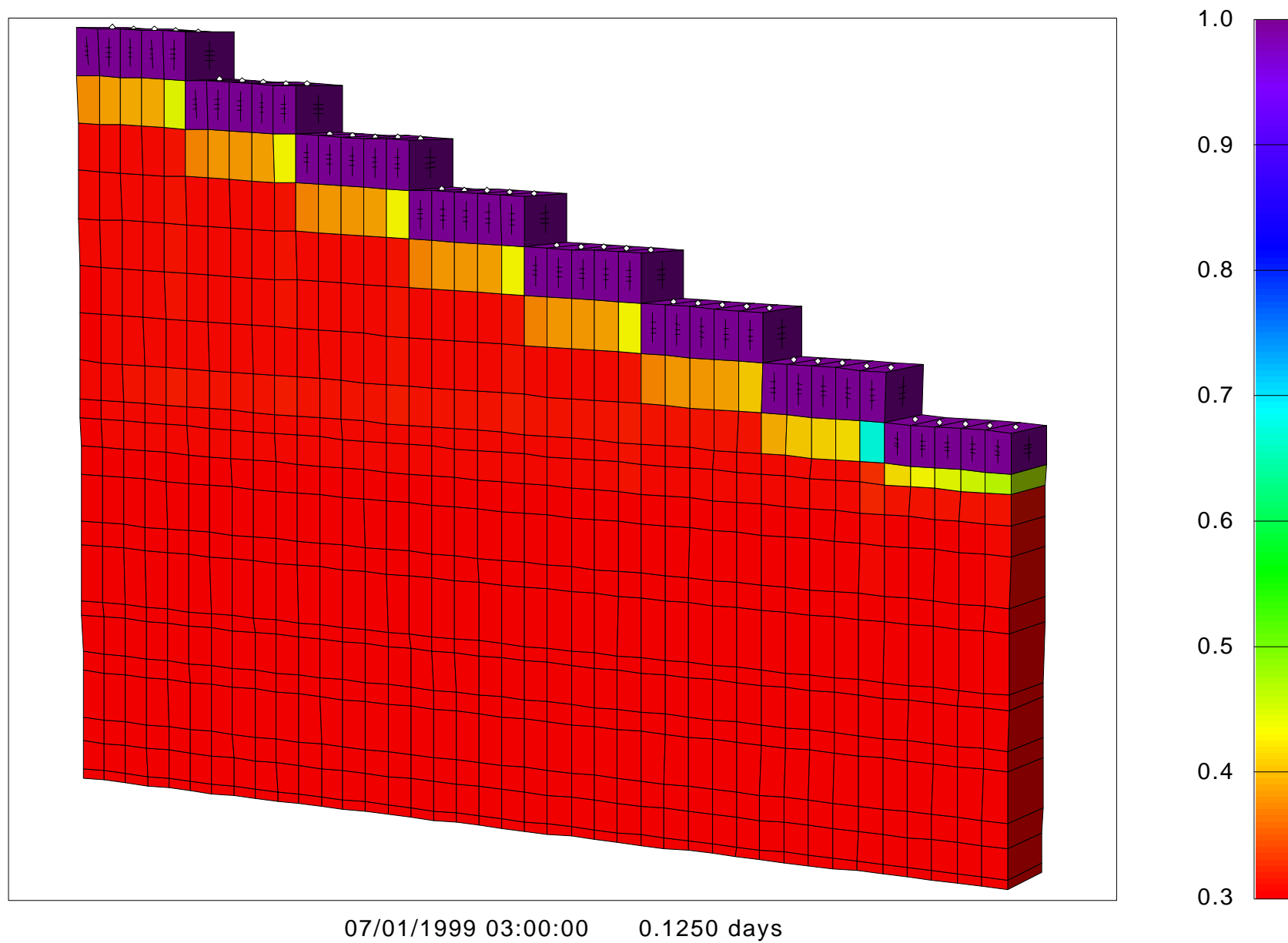


Initial Residual Water Saturation With Mountain Slope



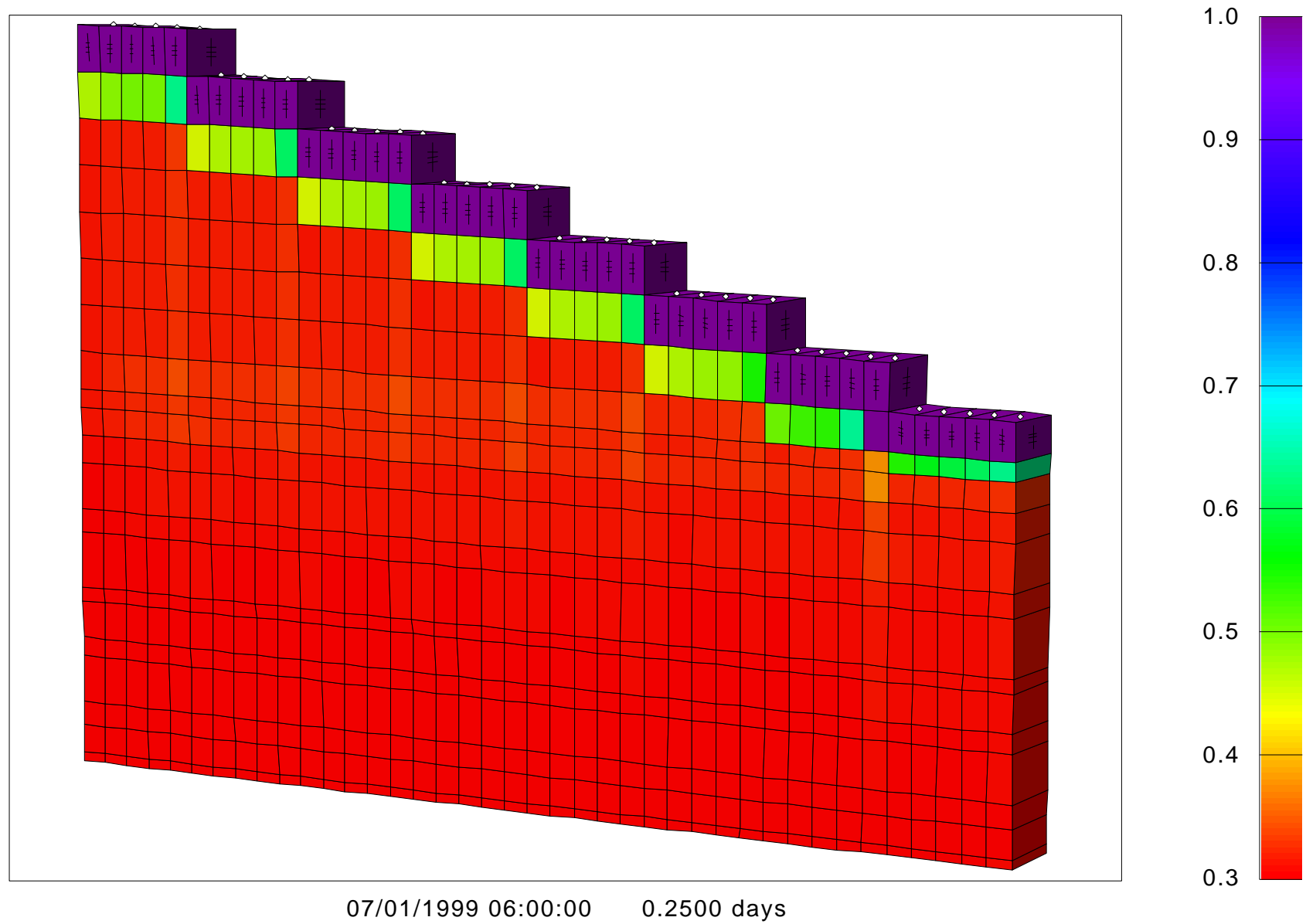
Water saturation after 3 hours

Test5a - Water Saturation



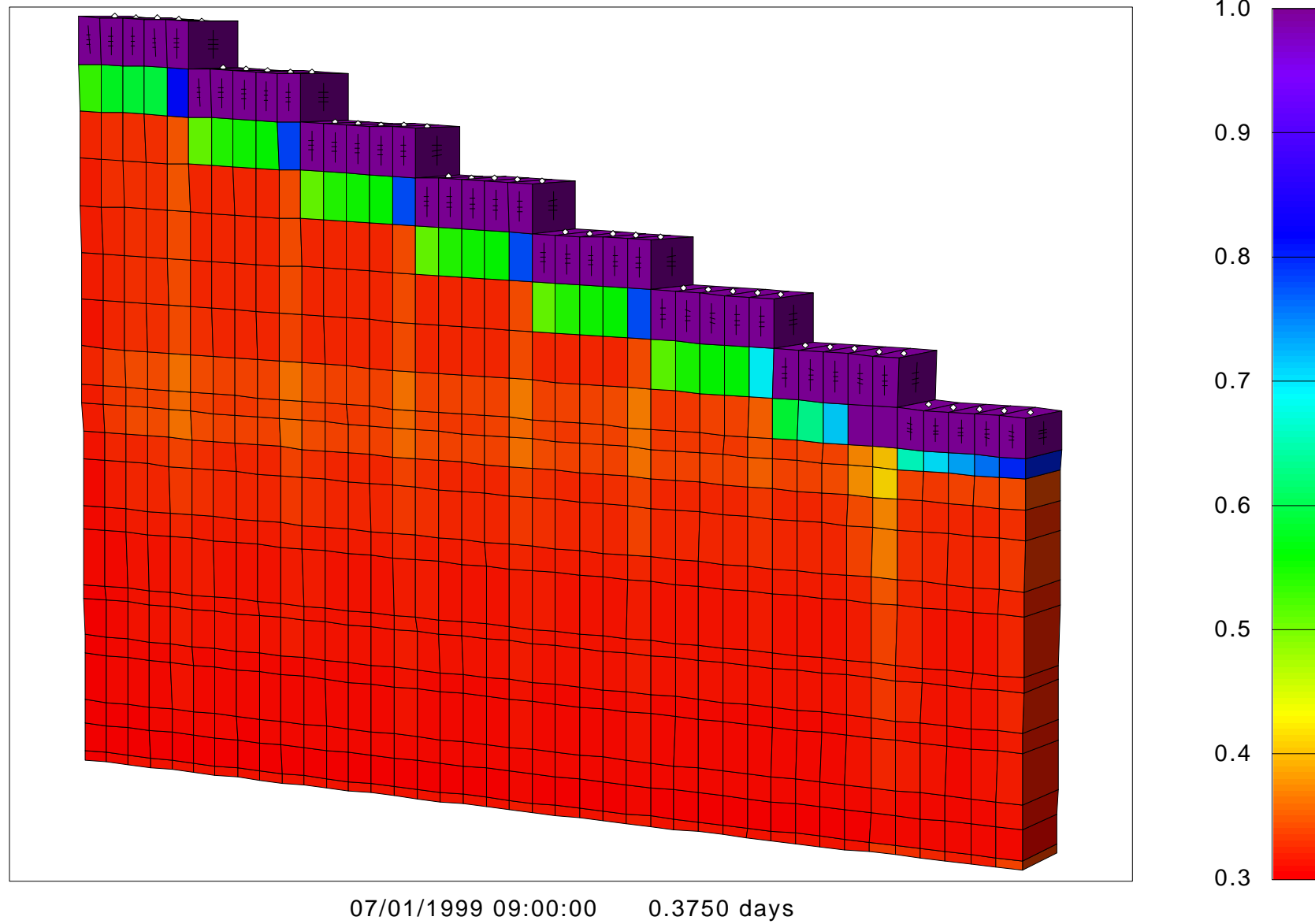
Water saturation after 6 hours

Test5a - Water Saturation



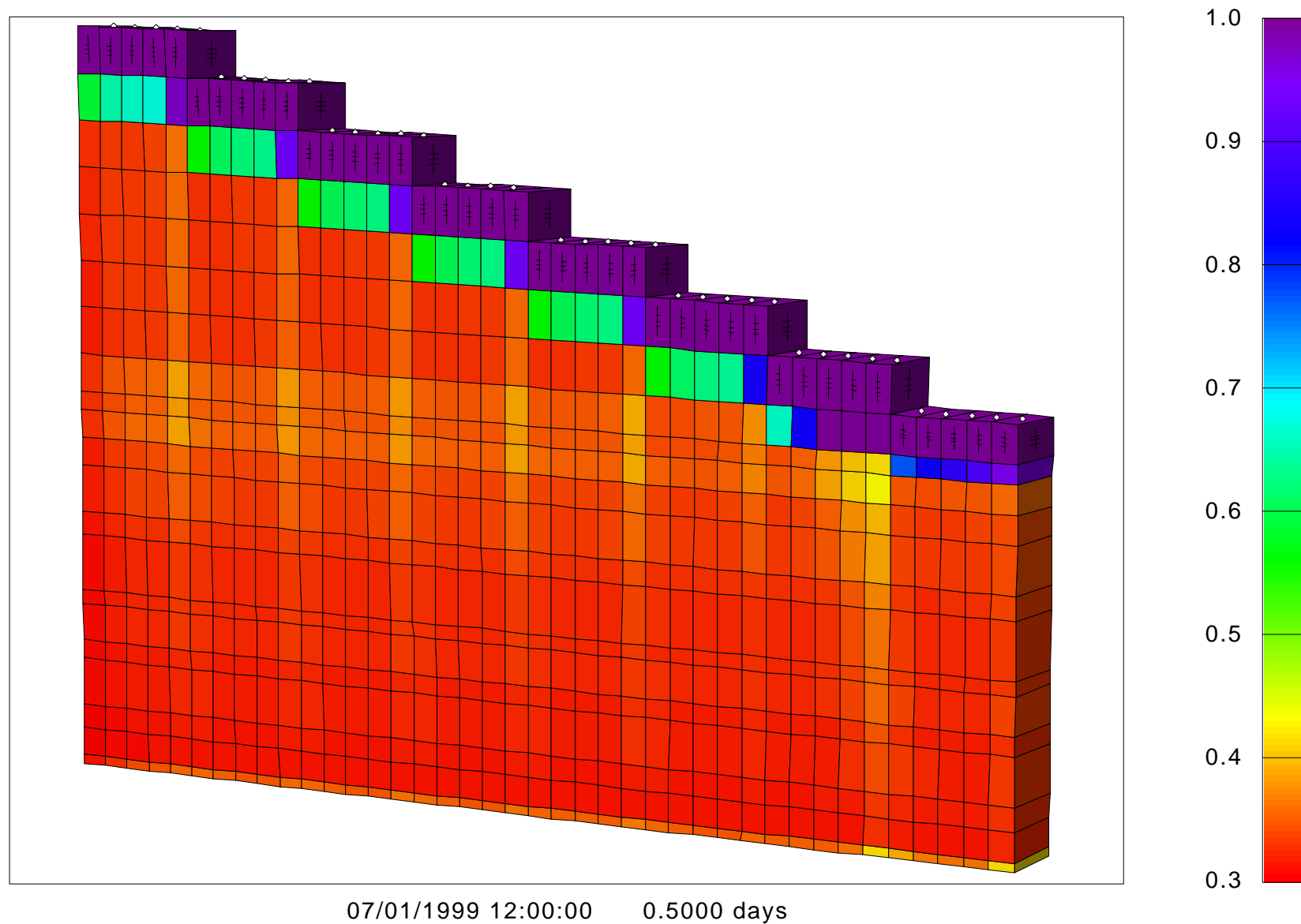
Water saturation after 9 hours

Test5a - Water Saturation



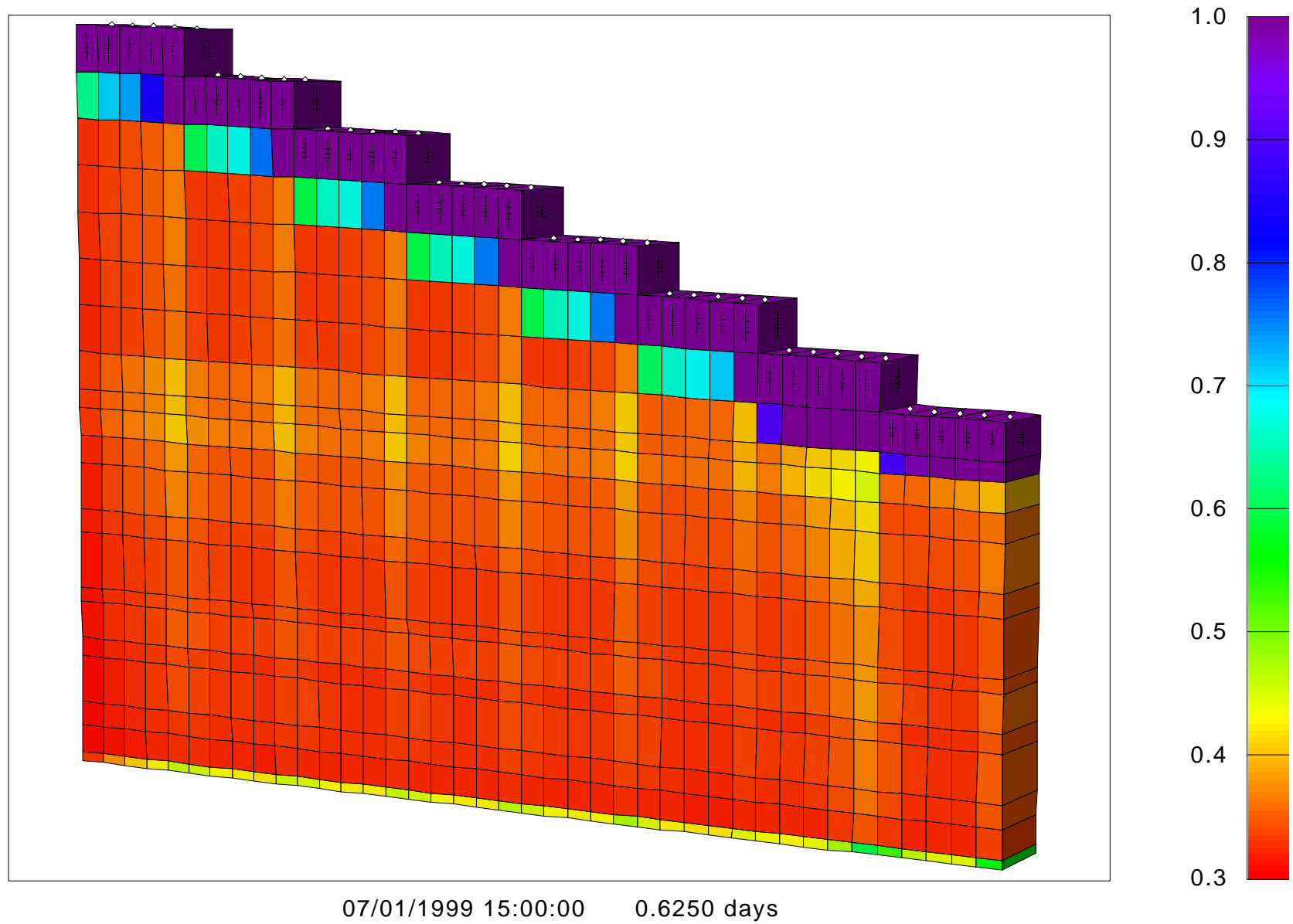
Water saturation after 12 hours

Test5a - Water Saturation



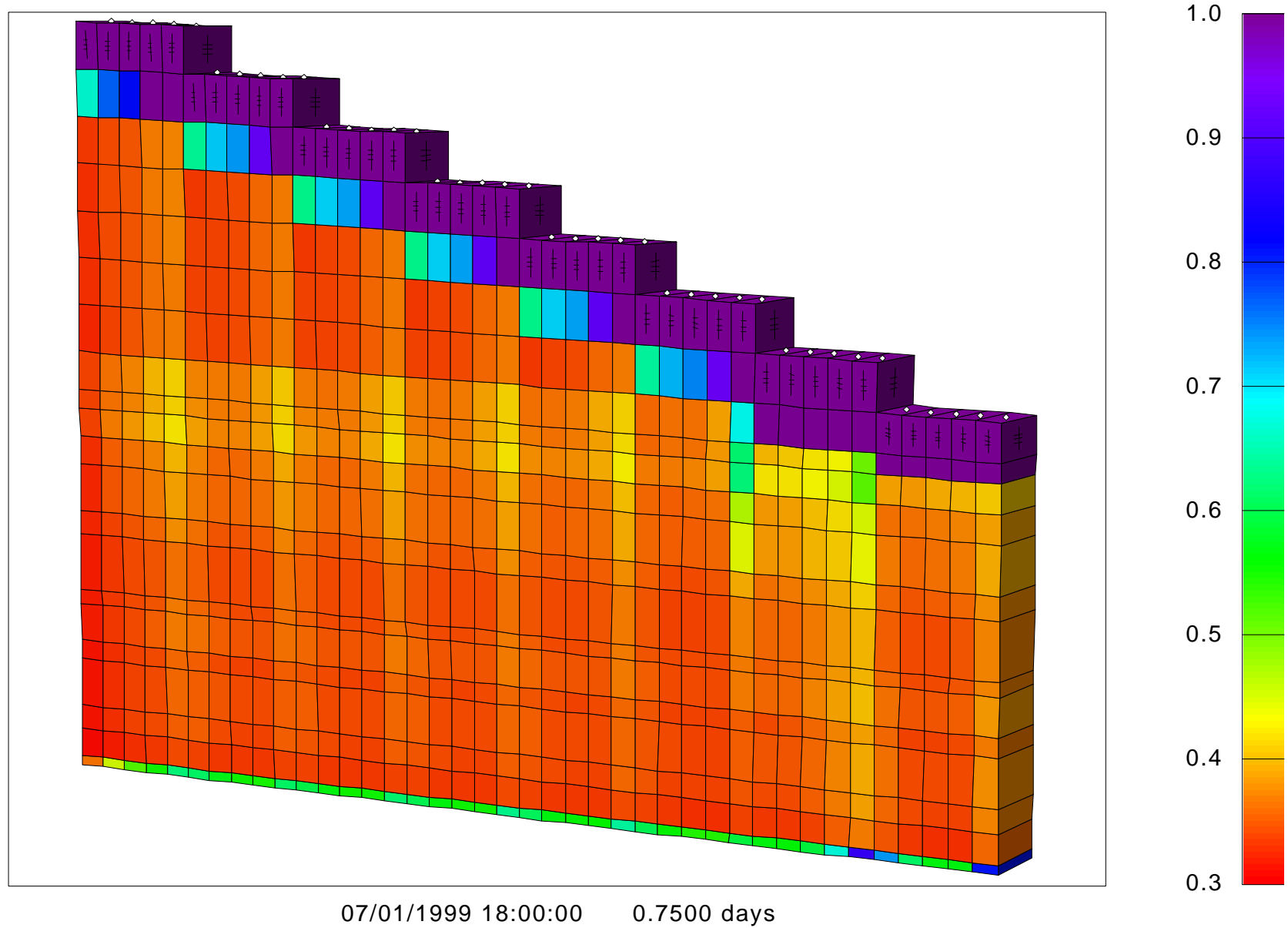
Water saturation after 15 hours

Test5a - Water Saturation



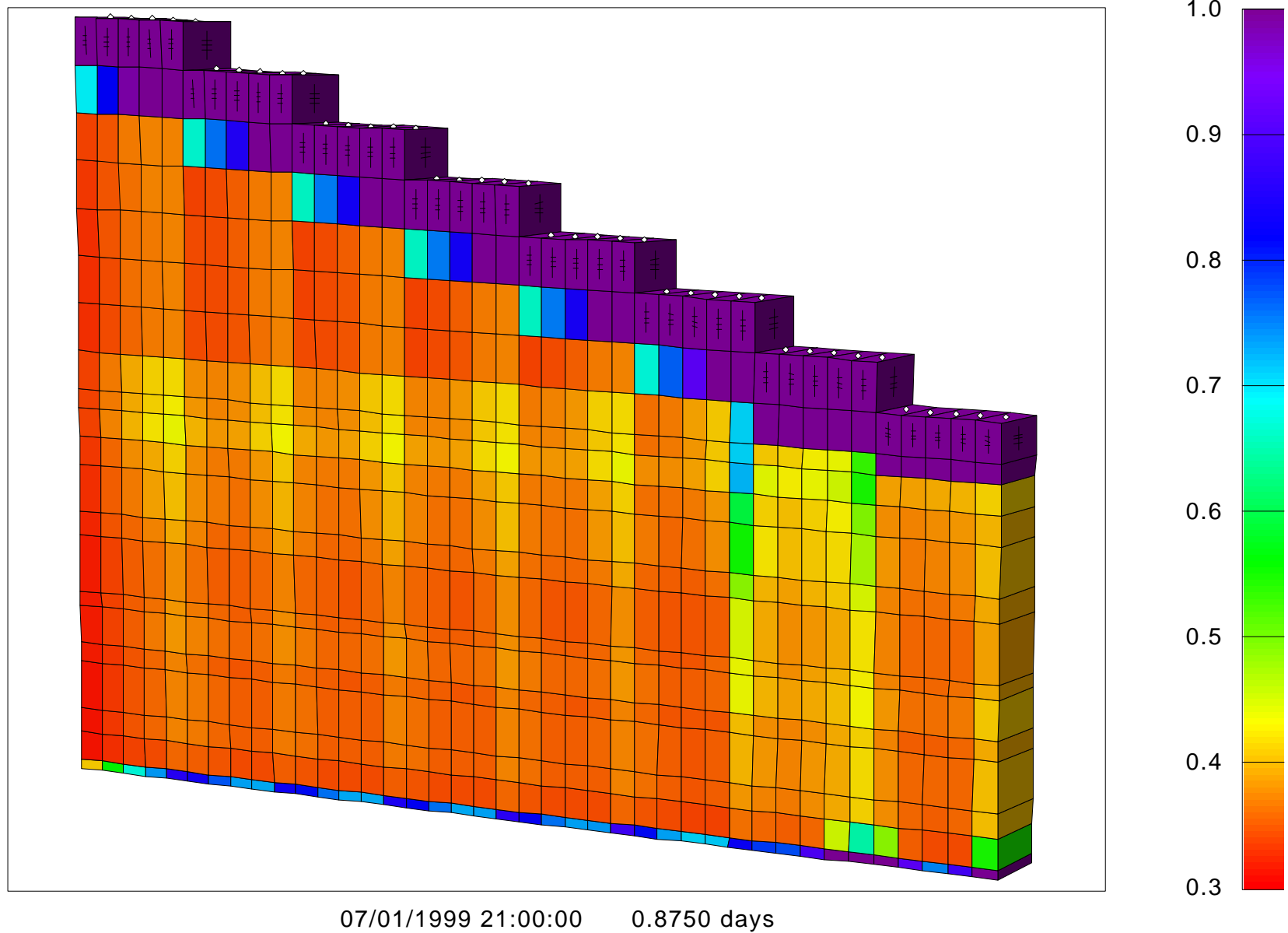
Water saturation after 18 hours

Test5a - Water Saturation



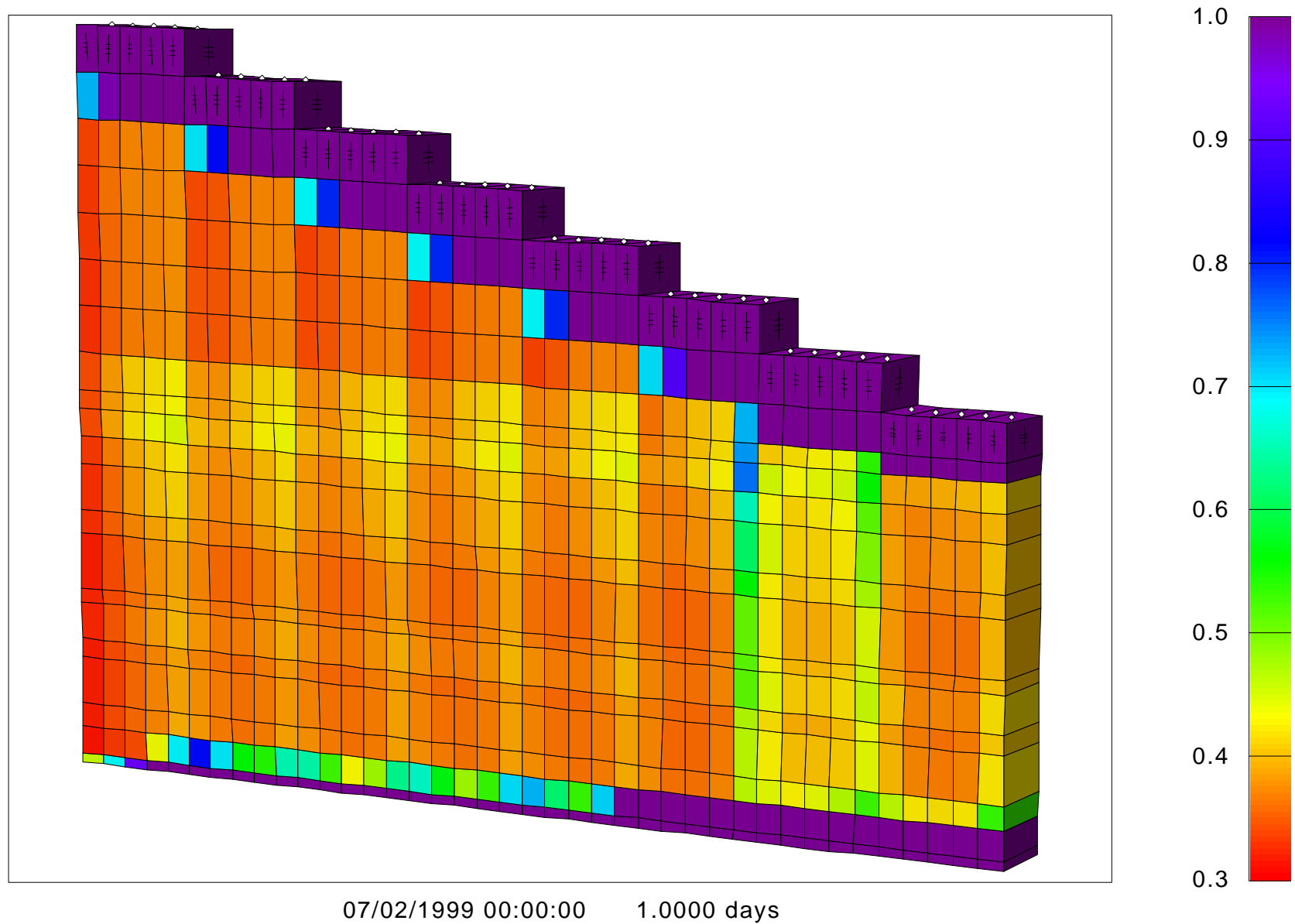
Water saturation after 21 hours

Test5a - Water Saturation



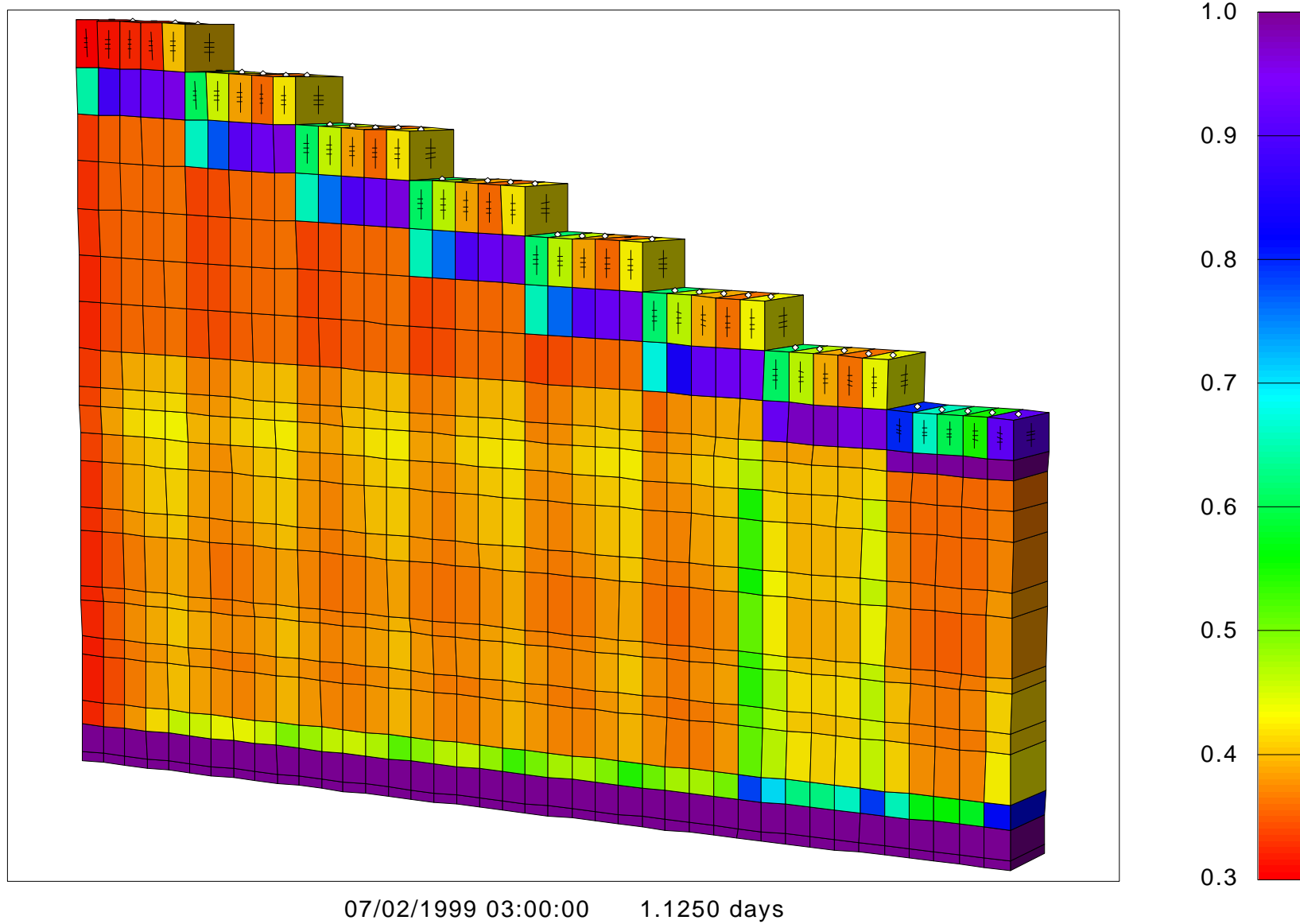
Water saturation after 24 hours - End Rainfall

Test5a - Water Saturation



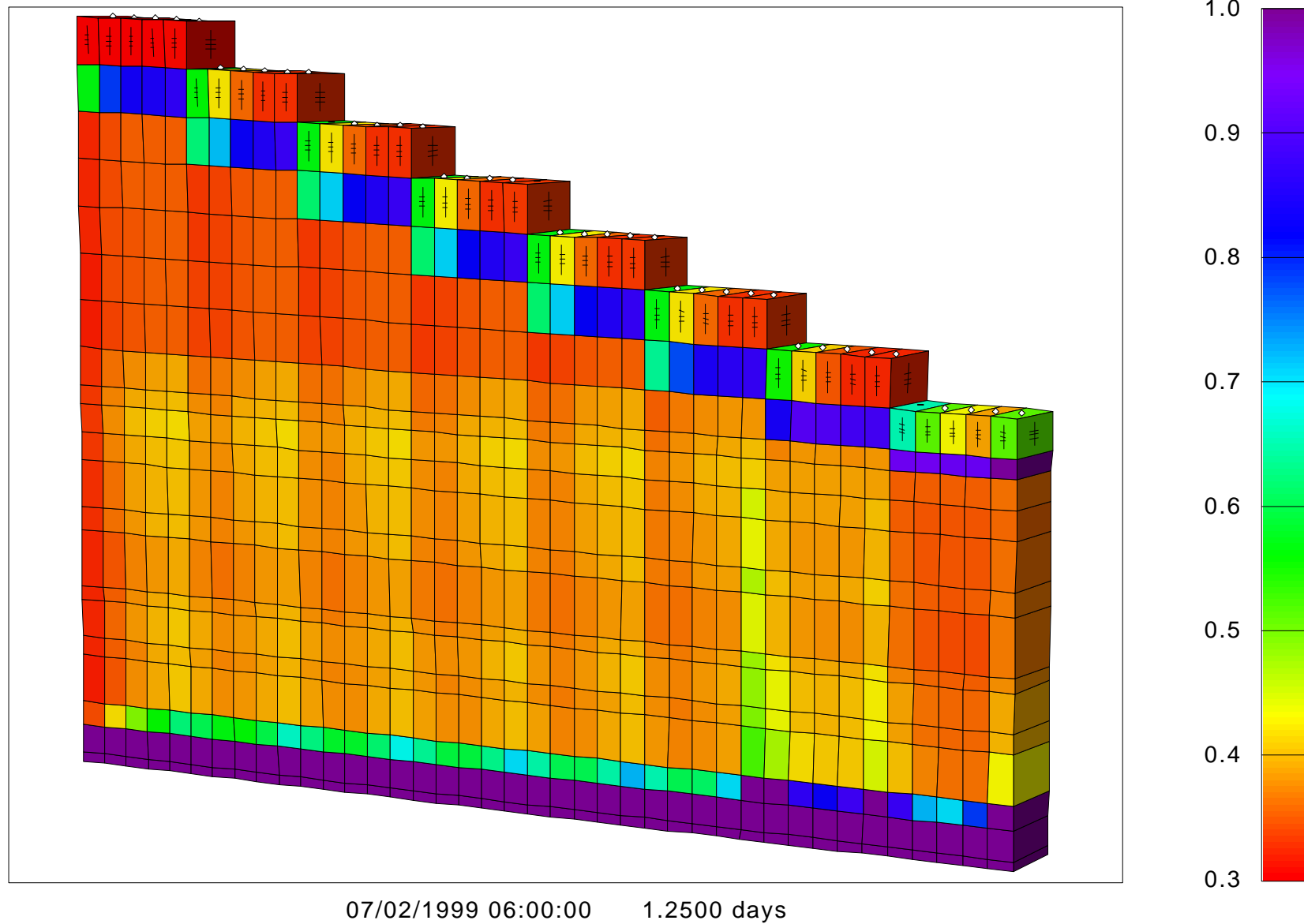
Water saturation after 27 hours

Test5a - Water Saturation



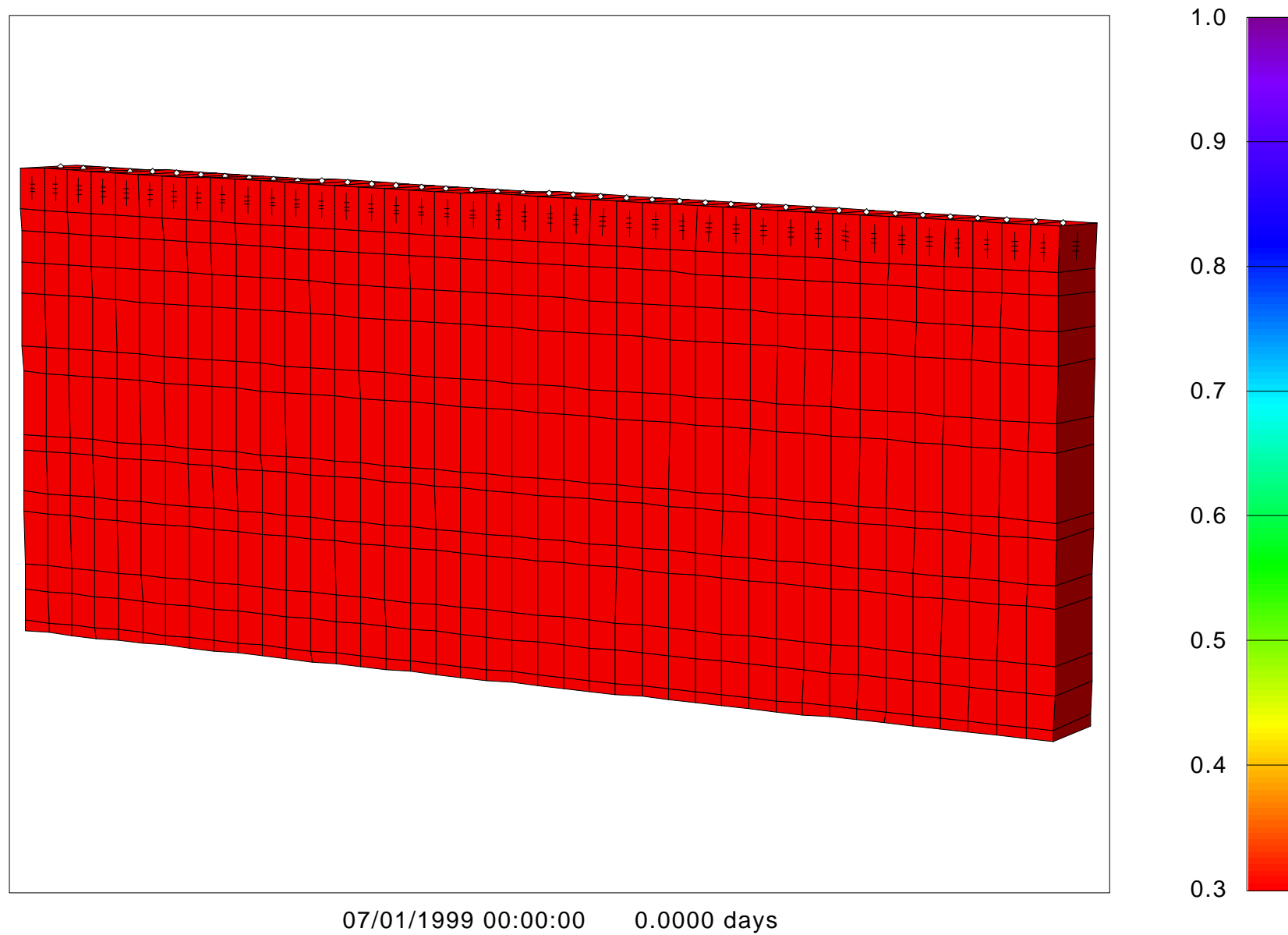
Water saturation after 30 hours

Test5a - Water Saturation



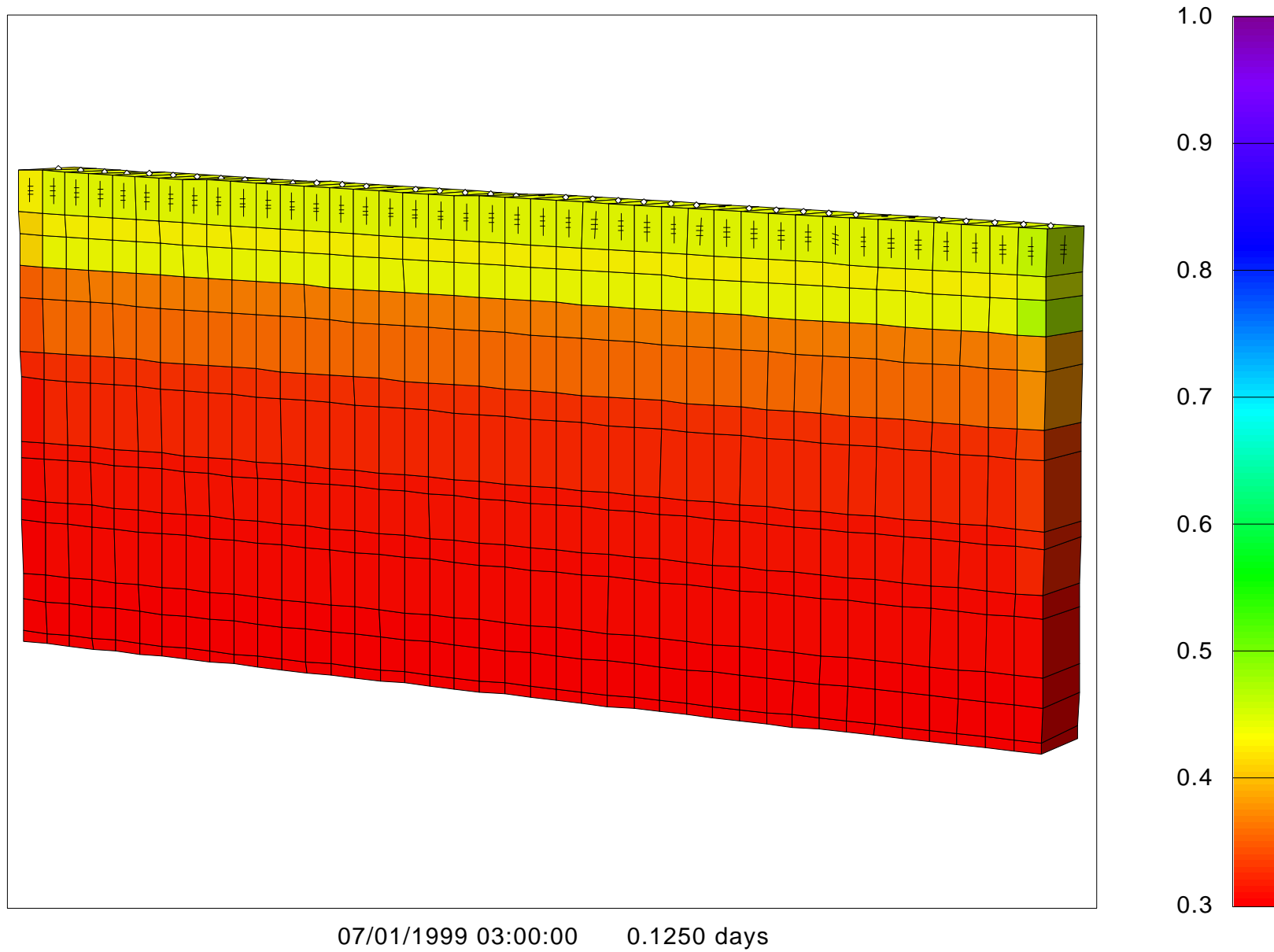
Initial Residual Water Saturation With Mountain Top Removal

test4 - Water Saturation



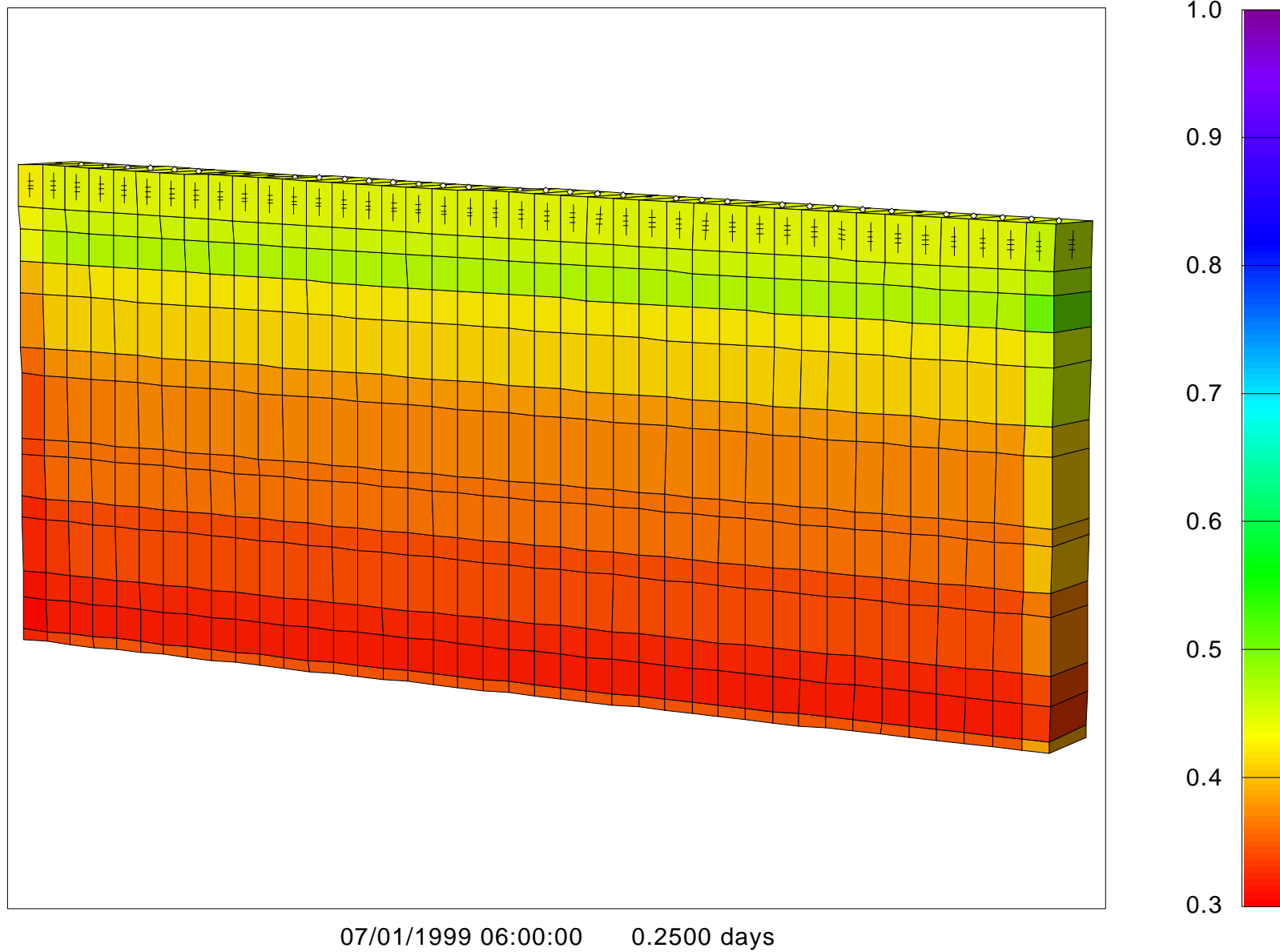
Water saturation after 3 hours

test4 - Water Saturation



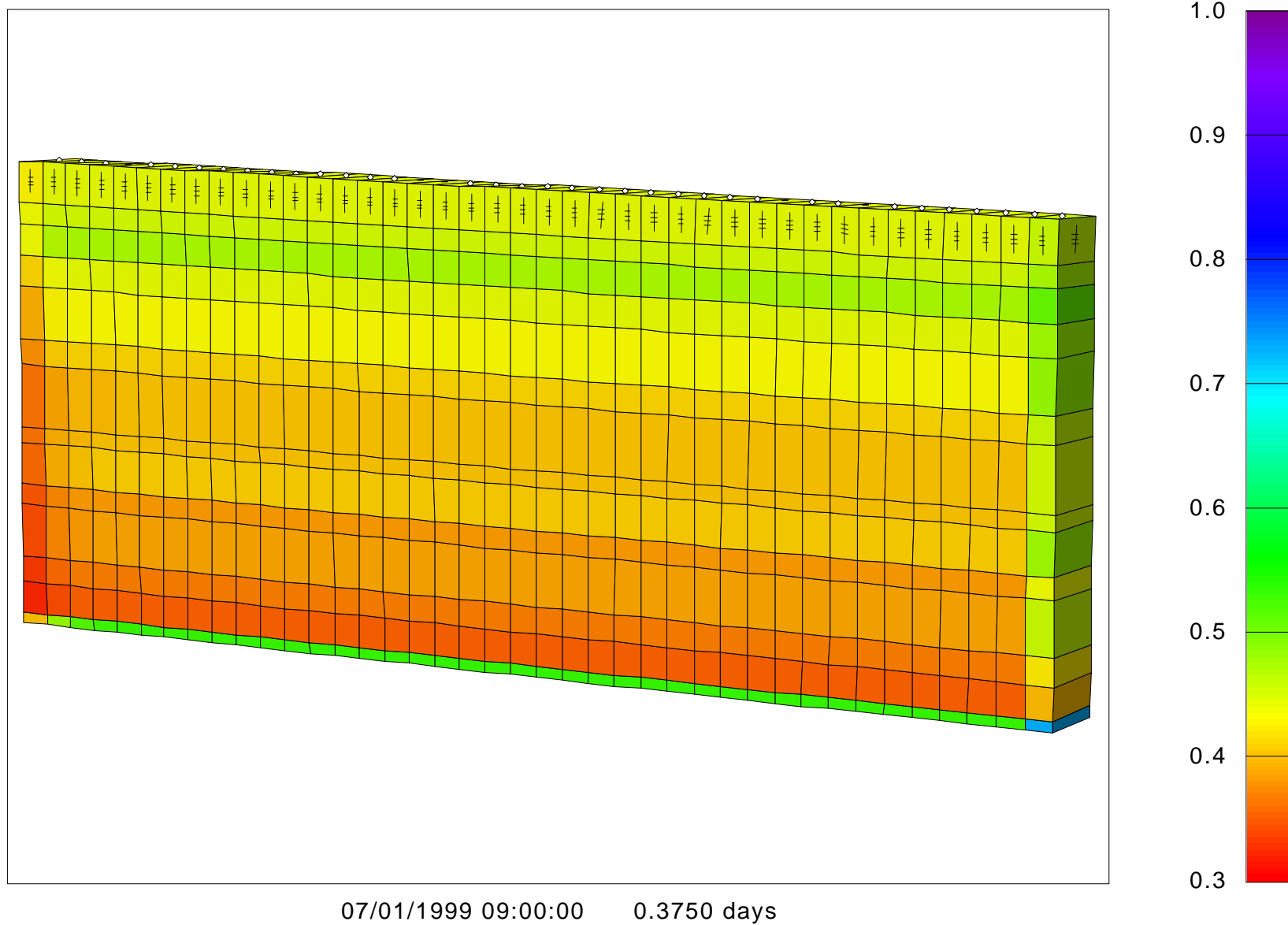
Water saturation after 6 hours

test4 - Water Saturation



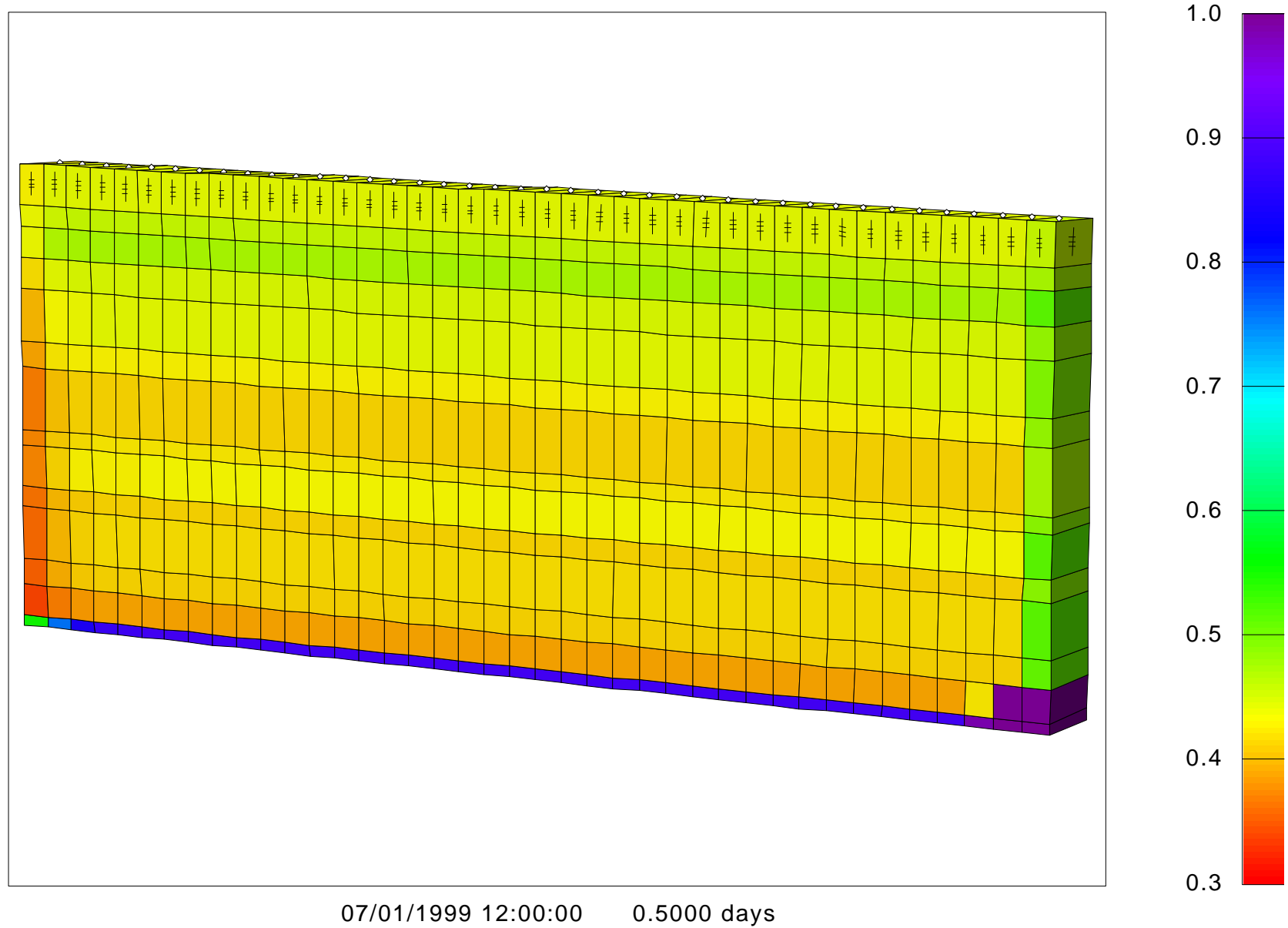
Water saturation after 9 hours

test4 - Water Saturation



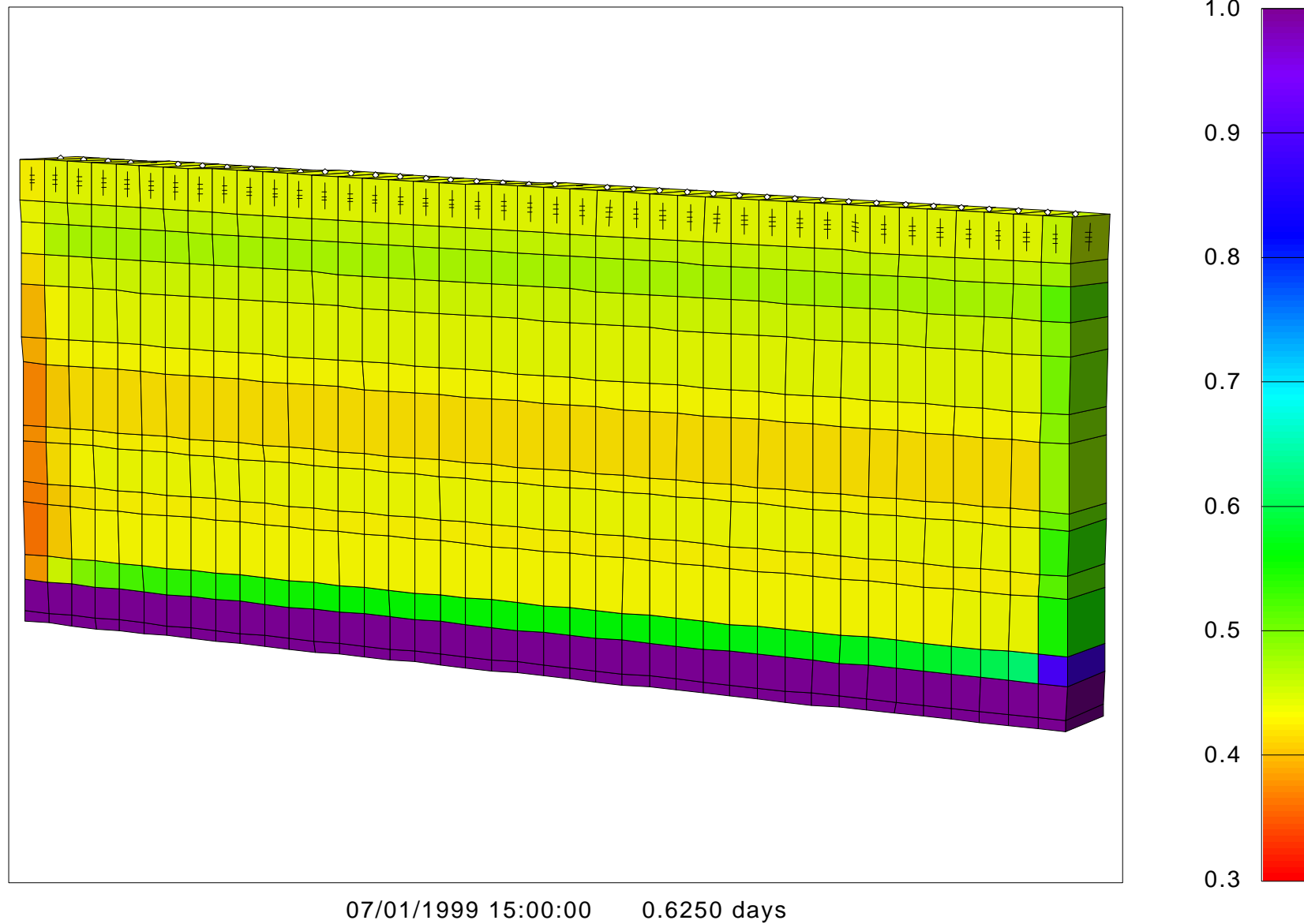
Water saturation after 12 hours

test4 - Water Saturation



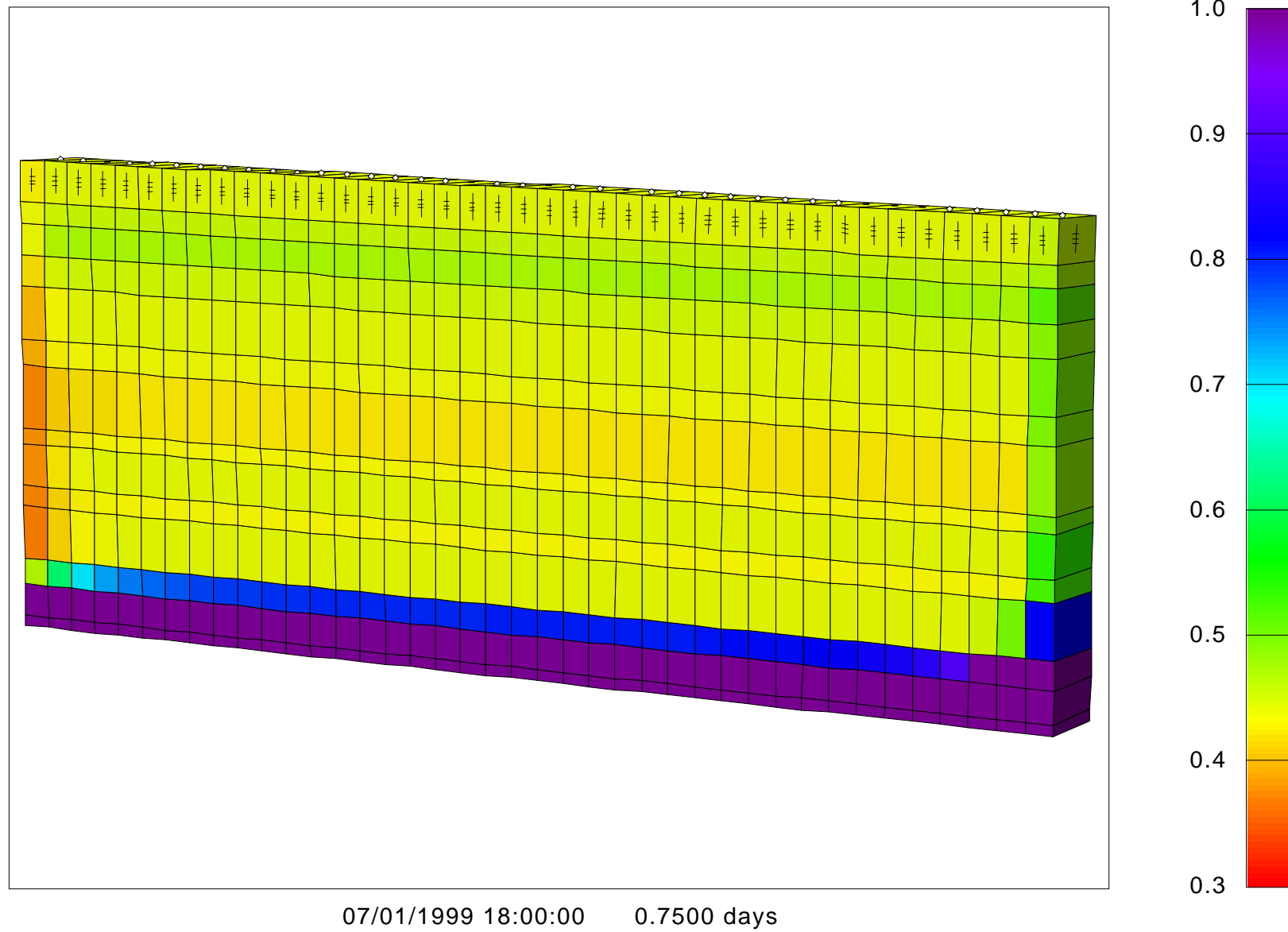
Water saturation after 15 hours

test4 - Water Saturation



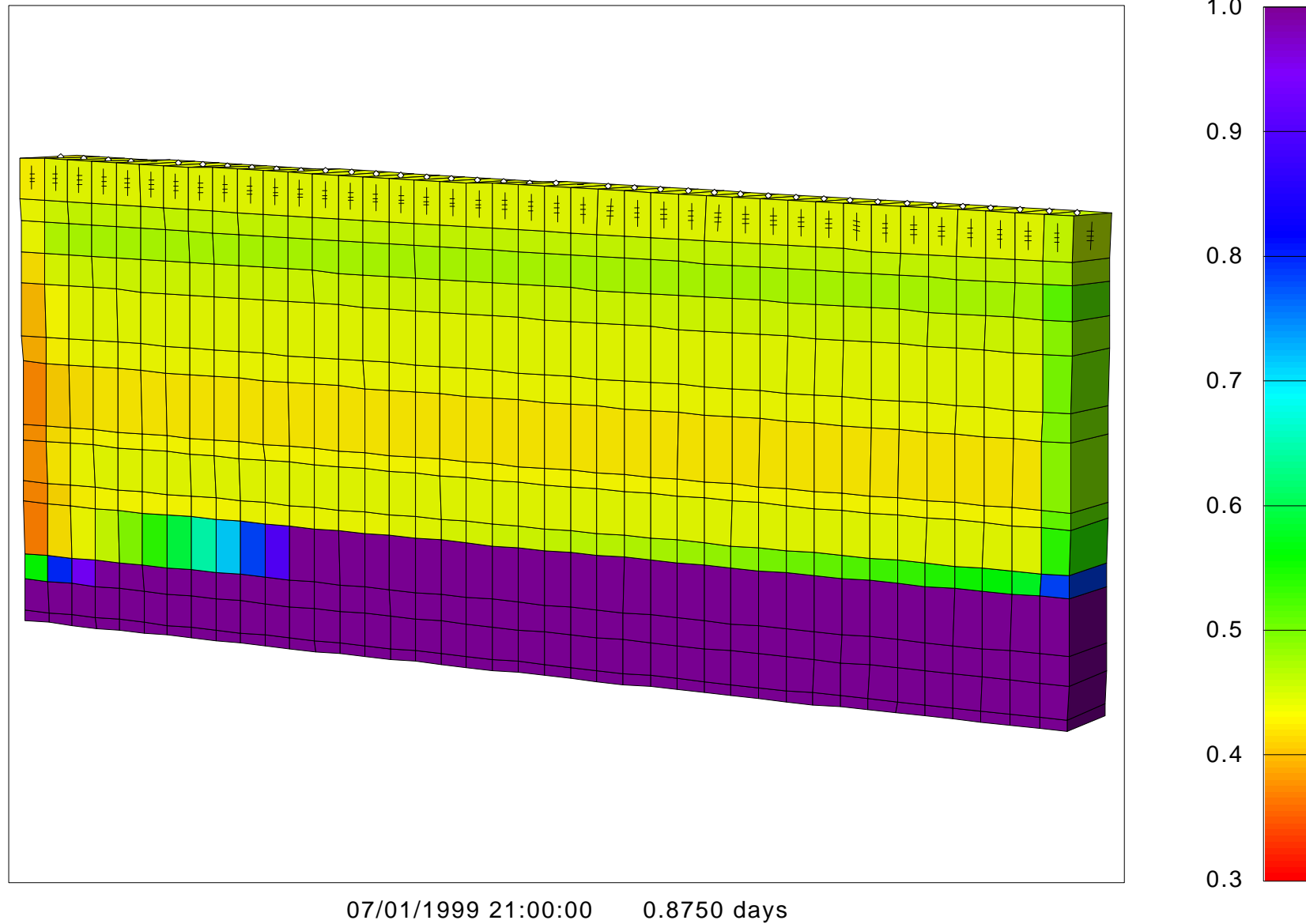
Water saturation after 18 hours

test4 - Water Saturation



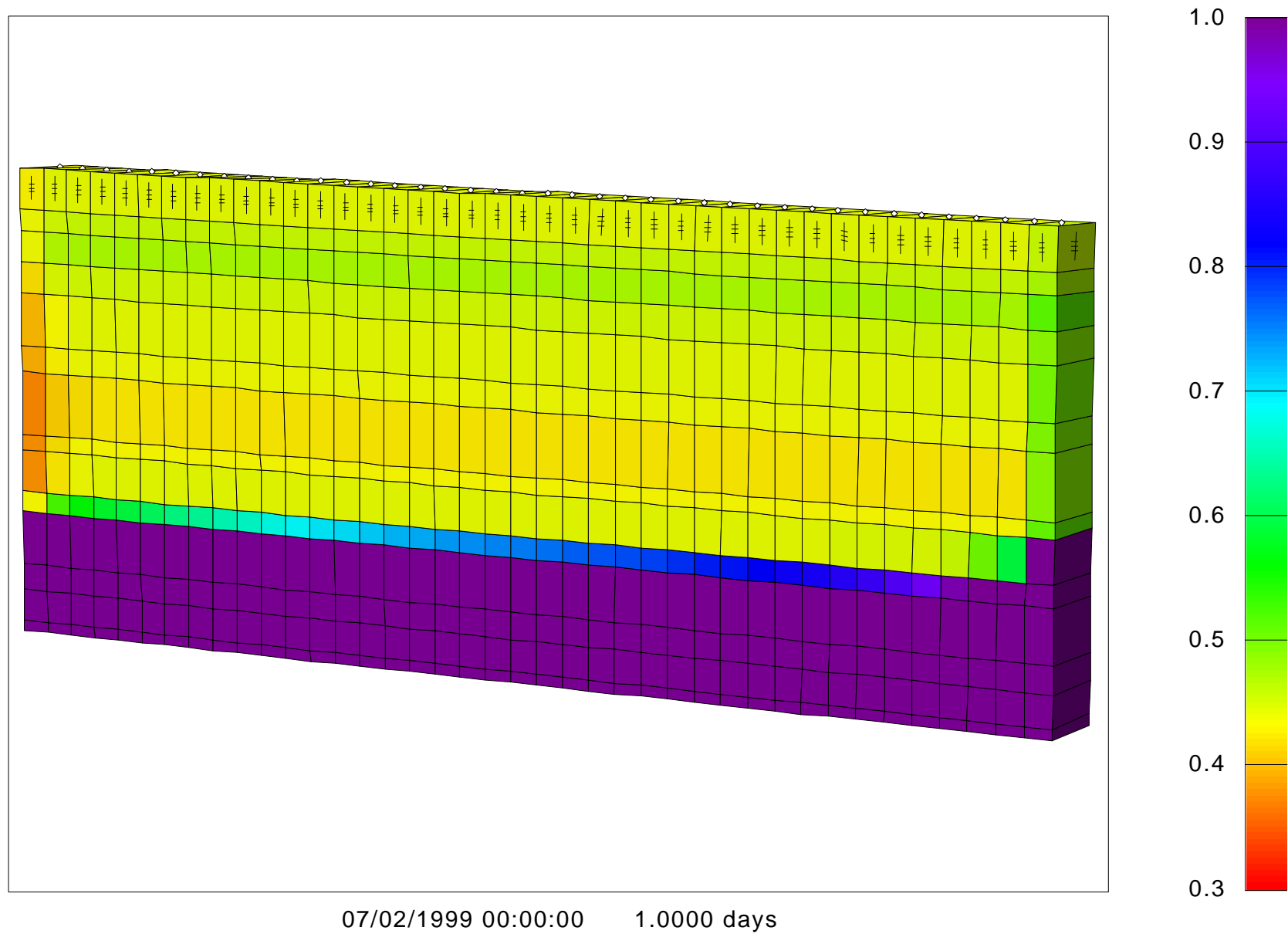
Water saturation after 21 hours

test4 - Water Saturation



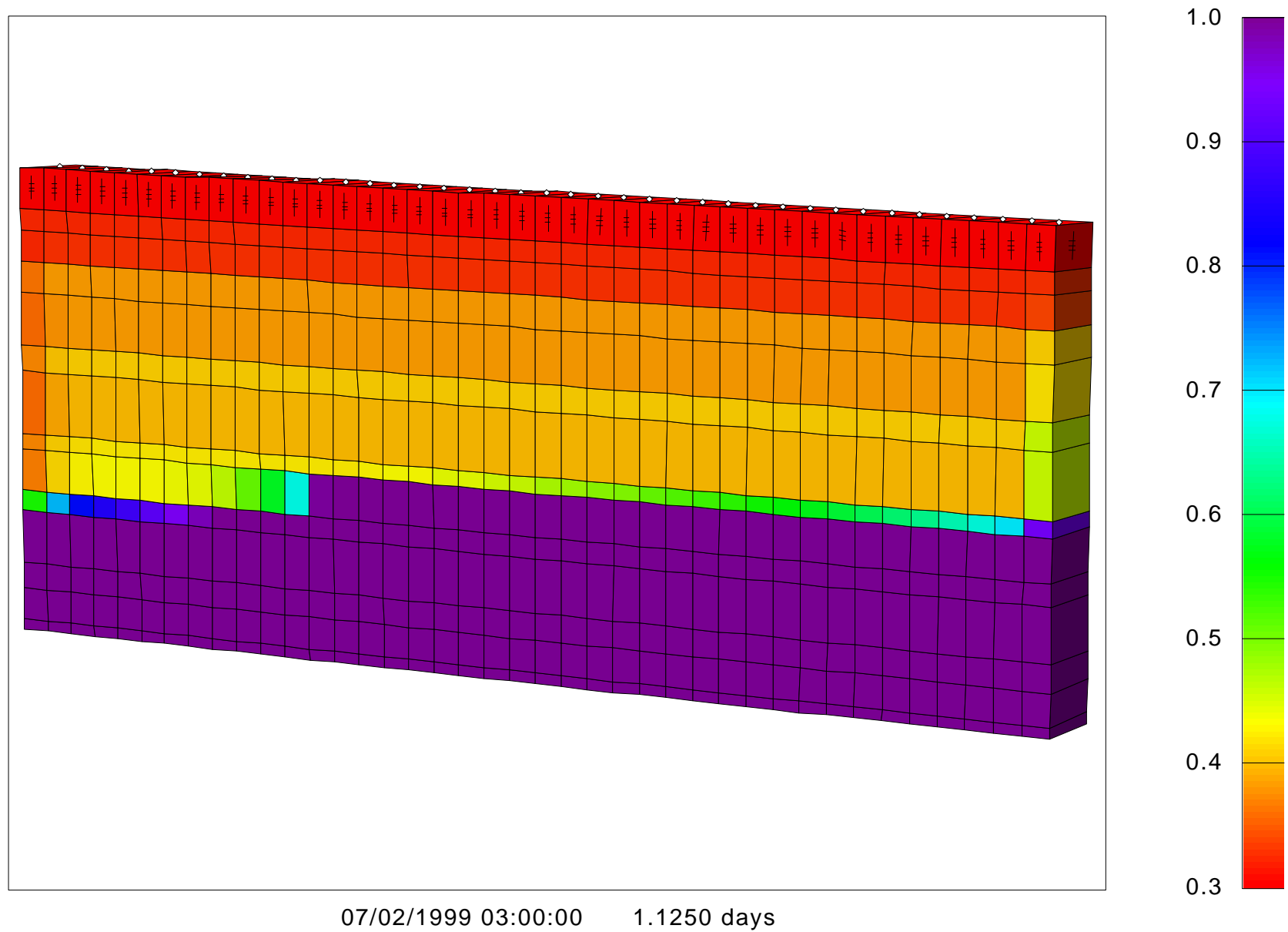
Water saturation after 24 hours - End Rainfall

test4 - Water Saturation



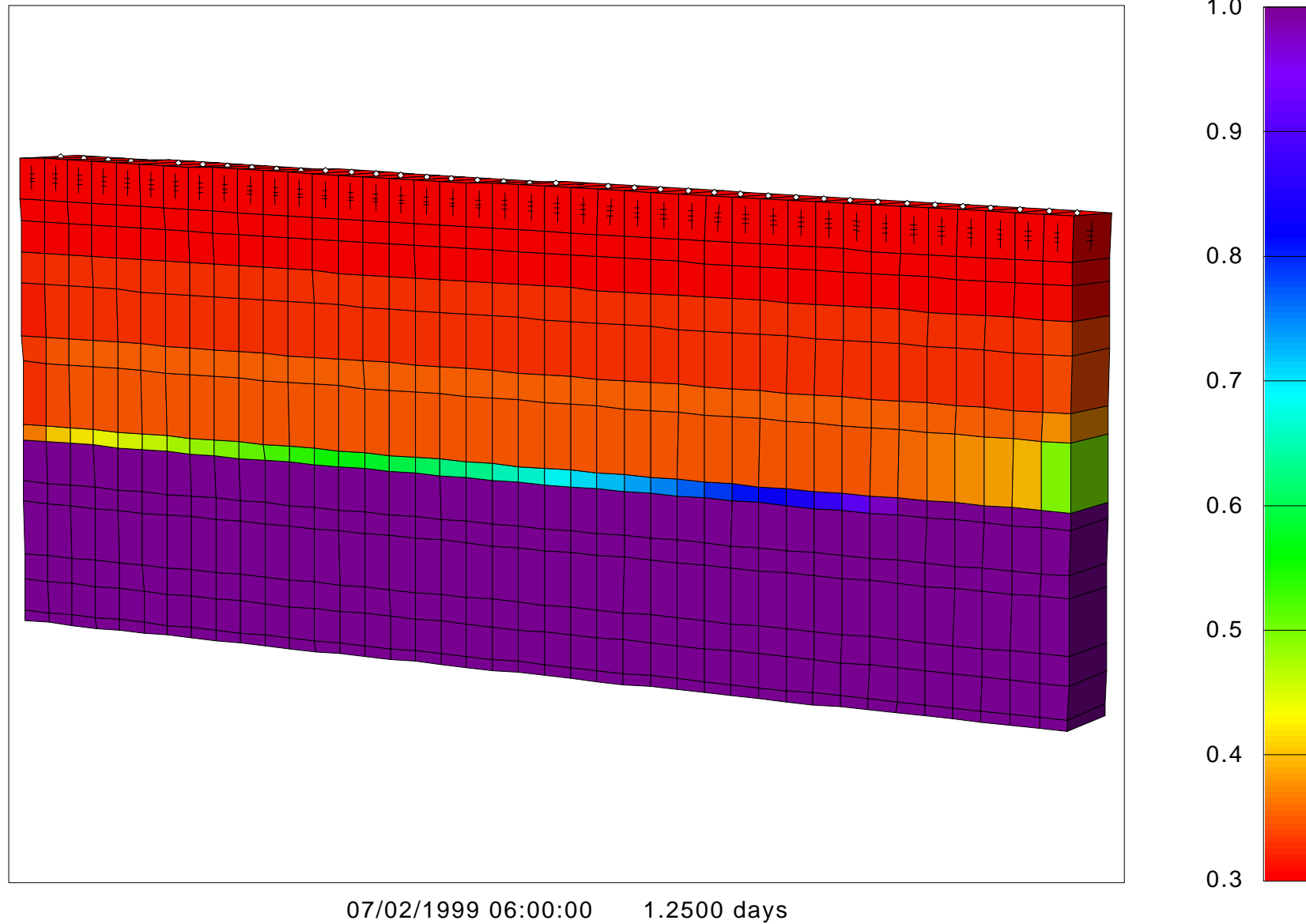
Water saturation after 27 hours

test4 - Water Saturation



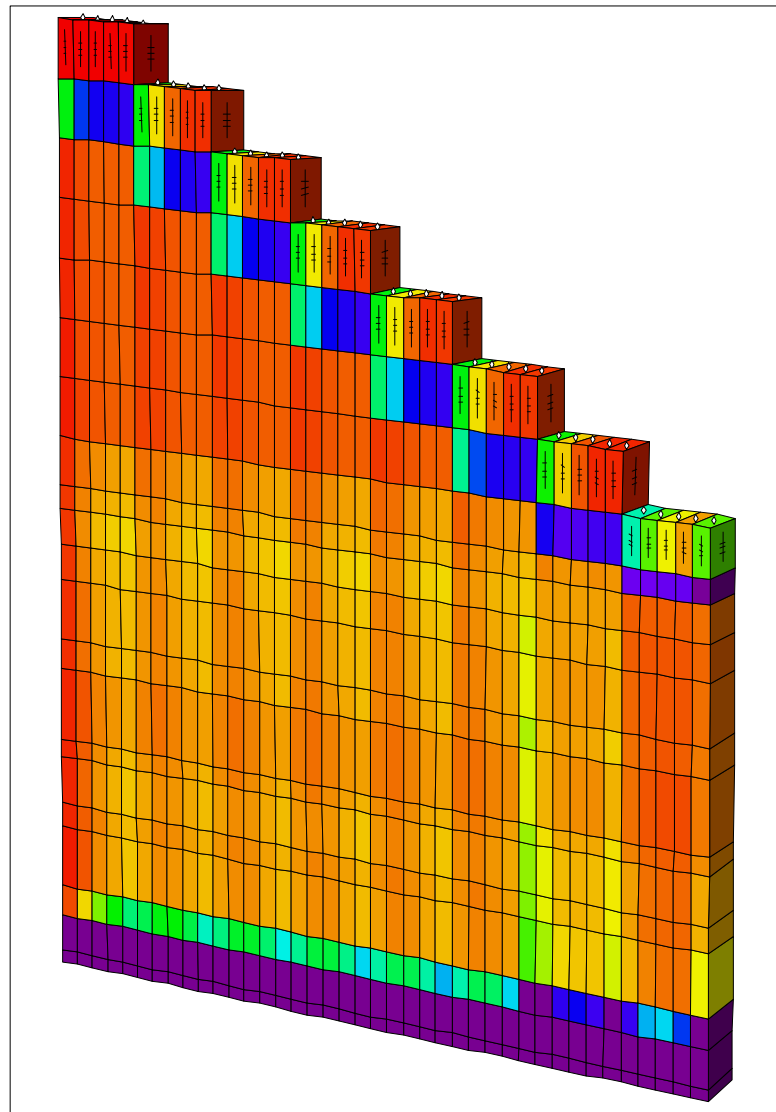
Water saturation after 30 hours

test4 - Water Saturation



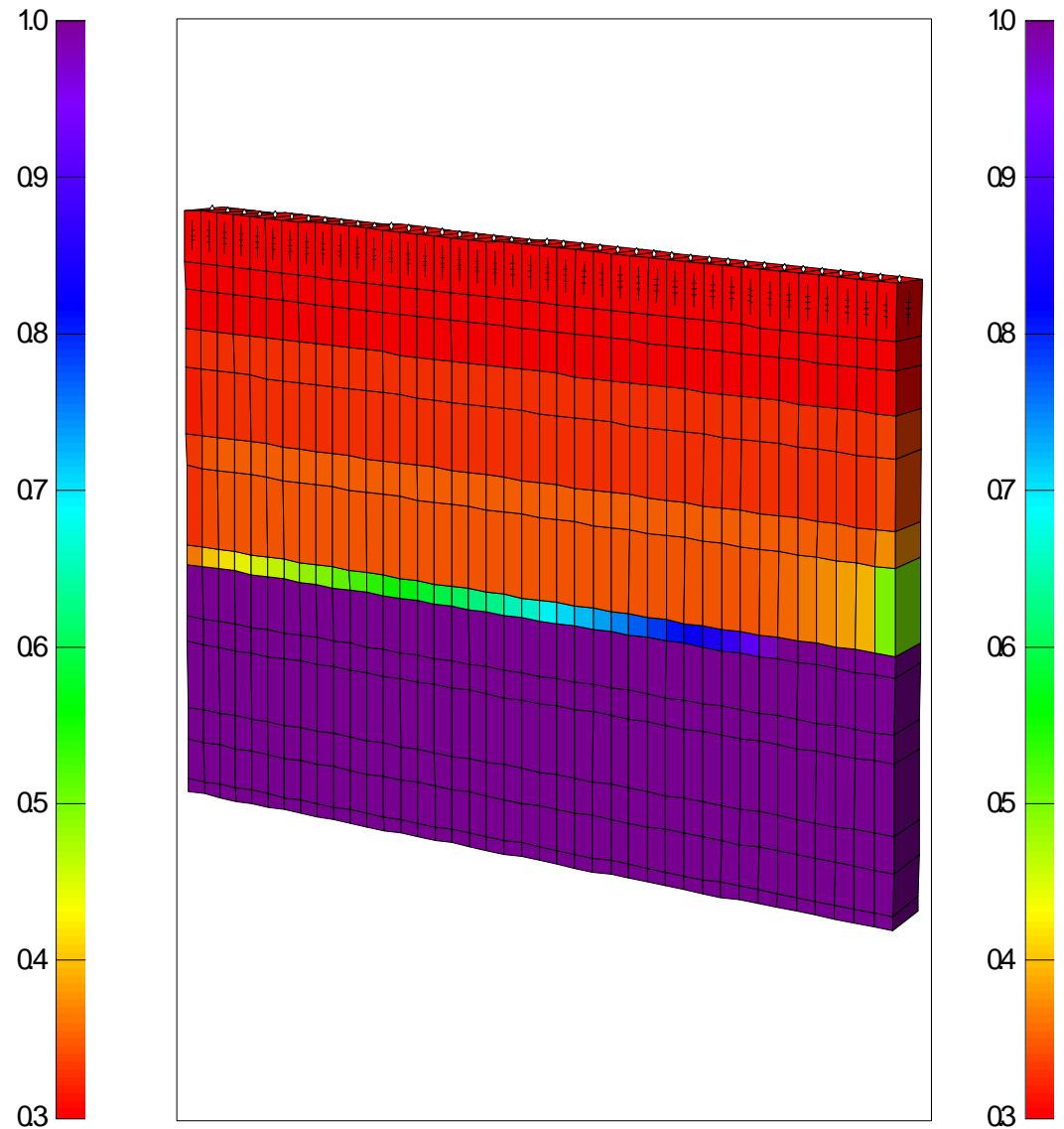
Increased Capture of Rain Water With Mountain Top Removal

Test5a - Water Saturation



07/02/1999 06:00:00 1.2500 days

test4 - Water Saturation



07/02/1999 06:00:00 1.2500 days

VITA: LEONARD C. NELSON

EDUCATION

Bachelor of Science Degree in Mechanical Engineering, Iowa State University, Ames Iowa

Master of Science Degree in Mechanical Engineering, University of Missouri at Rolla Missouri

Doctor of Philosophy Degree in Engineering, Northwestern University, Evanston Illinois

PROFESSIONAL EXPERIENCES

Mechanical Engineer, Fisher Body Division of General Motors Corporation, Detroit Michigan

Engineering Officer, United States Navy

Assistant Professor of Mechanical Engineering, University of Missouri at Rolla Missouri

Associate Professor of Mechanical Engineering, North Carolina State University at Raleigh North Carolina

Professor of Engineering, West Virginia Institute of Technology at Montgomery West Virginia

Dean, West Virginia Institute of Technology

President, West Virginia Institute of Technology

SPECIAL RECOGNITIONS

Member, Tau Beta Pi, Engineering Honorary Fraternity

Recipient, Murphy Foundation Scholarship and Pure Oil Fellowship at Northwestern University

Honorary Doctorate of Engineering, West Virginia Institute of Technology

Leonard C. Nelson College of Engineering, Named by Faculty of West Virginia Institute of Technology

PROFESSIONAL AND CIVIC ACTIVITIES

Member Board of Directors and President for Two Terms, Montgomery Chamber of Commerce

Member Board of Directors, Upper Kanawha Valley Economic Development Association

Member, American Association of State Colleges and Universities

BIOSKETCH OF WALTER K. SAWYER

Experience

33 years professional experience including: laboratory research, computer modeling, project management, university teaching, and consulting services in the oil and gas industry.

Founder and President, Mathematical and Computer Services, Inc. (1980 – Present)
Senior Petroleum Engineer, H-RT Consulting Services, Schlumberger (1995 – Present)
Associate Professor Petroleum Engineering, WVU (1978 – 1982)
Research Mathematician, U.S. Dept. of Energy (1966 – 1978)

Education

Glenville State College – B.S. Chemistry (1965)
West Virginia University – M.S. Mathematics (1973)
Industry Schools:

Pennsylvania State University: Numerical Reservoir Simulation (1972)
The University of Tulsa: Well Test Analysis (1973)
Scientific Software Corporation: Reservoir Simulation (1976)
Texas A&M University: Advanced Petroleum Reservoir Engineering (1977)
Physics International, Inc.: Continuum Mechanics (1976)
Joshi Production Technologies: (Horizontal Drilling (1990)

Publications and Presentations

22 Publications
6 Short Courses

“Reservoir Simulation as an Engineering Tool,” U.S. Department of Energy, Morgantown, WV, September 1983.
“Simulation Methane Reservoir Engineering,” Eastern States Exploration Company, Alexandria, VA, August 1991.
“Advanced Coalbed Methane Reservoir Engineering,” University of Alabama, College of Continuing Studies, April 6-8, 1994.
“Applied Reservoir Simulation,” CNG Transmission Corporation Clarksburg, WV, April 1997.
“Coalbed Methane Engineering,” University of Alabama, College of Continuing Studies, May 1999.

Professional Affiliations

Registered Professional Engineer, PA
Society of Petroleum Engineers of AIME
Pi Epsilon Tau
Pi Mu Epsilon

BIOSKETCH OF L. ZANE SHUCK

EXPERIENCE

42 years professional experience, including: college and university teaching, research and administration; planning, conducting and managing national energy research programs; consulting with industry; oil and gas well operator in WV & OH including developing over 65 wells; conducting interdisciplinary research in biomechanics and rheology; and, proprietor and executive officer in consulting and R & D companies. Inventor, and real estate developer.

President, Technology Development Inc. (1980-present)
Founder and President, The WMAC Foundation (1997-present)
WVU, Professor Mechanical Engineering and Associate Director, Engineering Experiment Station. Member Graduate Faculty, master and doctoral theses advisor (1976-80). Adjunct Professor (1980-85)
US Dept. of Energy, Supervisory Mechanical Engineer(1970-76)
National Science Foundation Science Faculty Fellow, & Res. Engineer WVU (1965-70)
WVa Tech, Associate Professor & Chairman, Dept. of Mechanical Engineering(1960-65)

EDUCATION

BSME - W.Va. Institute of Technology, 1958
MSME -West Virginia University, 1965
Ph.D. - West Virginia University, 1970
Graduate, post-doctoral, and summer programs at Iowa State University, Wayne State University, and Massachusetts Institute of Technology

PUBLICATIONS AND PATENTS

62 publications, 12 patents (including first patent ever awarded through WVU), Producer 4 technical films for U.S. Dept of Energy

ANCILLARY INFORMATION

Registered Professional Engineer WV & OH; Certified by National Council of Engineering Examiners; Science Advisor WV Governor John D. Rockefeller IV (78-81); Science and Technology Coordinator WV Legislature(79-80); ASTM Award (70); ASME Ralph James National Award (80); Editor Transactions Journals and Symposia Proceedings; Licensed Surveyor WV